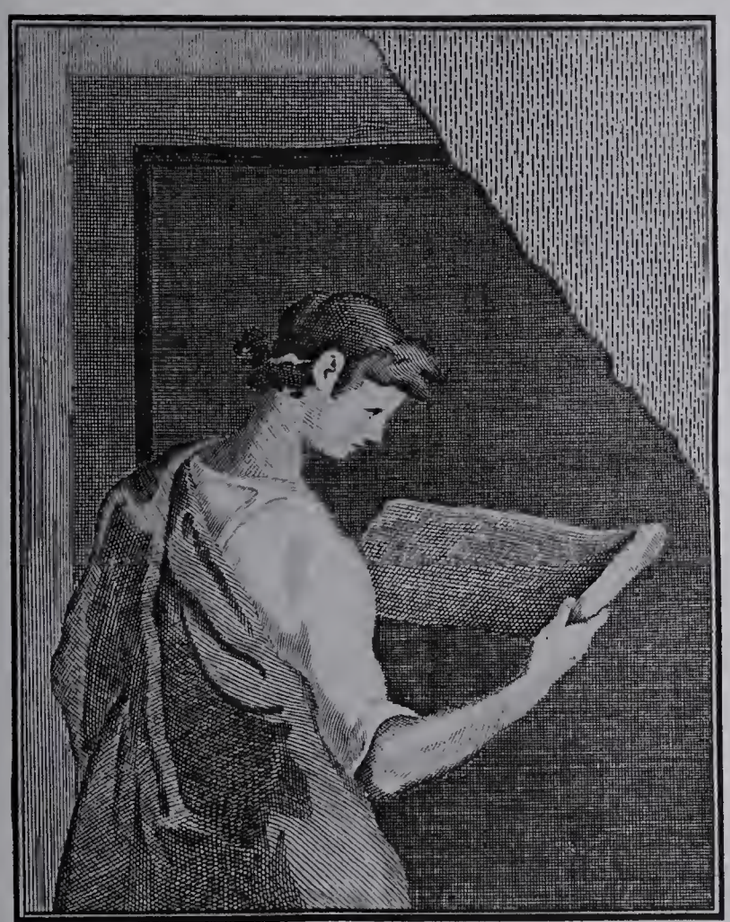
THE EARTHQUAKES OF ISCHIA



MONOGRAPH

OF

THE EARTHQUAKES OF ISCHIA

Fototip F^lli Doyen. Torino

Panorama of Casamicciola from near Frasso, 1881.

MONOGRAPH

OF

THE EARTHQUAKES OF ISCHIA,

A MEMOIR DEALING WITH THE SEISMIC DISTURBANCES IN THAT ISLAND FROM REMOTEST TIMES, WITH SPECIAL OBSERVATIONS ON THOSE OF 1881 AND 1883.

BY

H. J. JOHNSTON-LAVIS.

M. D., M. R. C. S., B. ès Sc., F. G. S. &c.

AND SOME CALCULATIONS BY

Rev. Prof. SAMUEL HAUGHTON M. D., D. C. L., F. R. S., F. G. S., &c.

WITH NUMEROUS PLATES AND PHOTOGRAPHS.

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TO

THERESA, DUCHESS FIESCHI RAVASCHIERI,

AND TO

MADAME OSCAR MEURICOFFRE,

AS A TOKEN OF RESPECT
FOR THEIR LONG-CONTINUED, EMINENTLY PRACTICAL,
AND CHARITABLE EXERTIONS,
AMONGST THE UNFORTUNATE SURVIVORS
OF THE CATASTROPHE OF 1883,

THIS WORK IS DEDICATED

BY

THE AUTHOR.

PREFACE

After the earthquake of Ischia in 1881 I had prepared an account of that catastrophe; but, from the pressure of professional duties, it was not completed when the greater disaster of 1883 occurred. It, therefore, became necessary to add a much larger bulk of descriptive matter, relating to the earthquake of 1883, and to remodel the chapters containing the deductions and conclusions, resulting from the double set of data. On this occasion less time was taken in completing the monograph as it now stands, and early in 1884 it was placed in the hands of Prof. Archibald Geikie for presentation to the Royal Society of London. Its bulk and the large number of illustrations rendered it in the eyes of the council beyond the limits of the «Transactions», so that, by the advice of Prof. Geikie, I undertook to publish it by subscription. Before, however, the Royal Society came to a final conclusion, the paper was presented at various sittings previous to and after the autumn vacation. During this long delay, many important contributions had been made to the science of seismology, not the least of which is the valuable memoir of Prof. F. A. Ewing F. R. S. E. on «Earthquake Measurement» published by the Science Department of the University of Tokio, Japan. Although some new and important facts are brought out in that work, it was thought better to leave this monograph in its original state.

Much has been said to disparage Mallet's method of investigating earthquakes by examination of the damage they cause to walls, buildings etc.; and no doubt such objections are to a considerable extent justified, and the preference that is given to instrumental measurement is quite reasonable. I entirely concur with this opinion myself; but many years must elapse before even such small areas as that of Ischia are sprinkled over with modern seismographic apparatus, directed by intelligent observers. It is clear therefore, we are justified in employing what means we have, until we can bring delicate instruments to our aid. These, without doubt, will be great improvements on the methods made use of in the preparation of this work, though they will be far from perfect; for, practically, it is impossible to obtain a «steady point» during an earthquake, and correct registration

will always be marred by friction and similar causes. Besides this, I have been convinced, somewhat against my will, that the older method is quite applicable in the two earthquakes herein studied; though whether it be of general application I do not feel justified in asserting.

The only important study of the Ischian earthquakes is by Prof. Giuseppe Mercalli « L'Isola d'Ischia ed il terremoto del 28 Luglio 1883. Milano 1884 », which appeared while my manuscript was in the hands of Prof. Geikie. The conclusions in that memoir are very similar to those contained in this monograph, and are in part founded on some of my own observations, for the latter of which the author gives full credit. I am bound, however, in justice to myself, to mention that I had published nearly all Prof. Mercalli's conclusions, relating both to the shock of 1881 and to that of 1883, very soon after each event, and long before the appearance of his memoir and (in most cases) before his local investigations. I had also explained my views to him on two occasions when he passed through Naples.

The general conclusions deduced from my observations may be found roughly stated in the following articles and notices from my pen: whilst they are worked out in greater detail in the present volume, viz. The earthquake in Ischia « Nature » March 24th 1881, Vol. XXIII. Preliminary notice of the earthquake of 1881, in the island of Ischia. Reports of the British Association 1883. The disaster in Ischia « Nature » August 9th 1883 Vol. XXXIII (dated Naples. July 30th), « L'Italie » August 31st 1883, and « Il Piccolo » Sept. 2nd 1883. The Ischian earthquake of July 28th 1883, « Nature » Sept. 6th 1883 Vol. XXXIII, and « L'Italie » of Sept. 22nd 1883 (dated Naples August 31st 1883). Preliminary notice on the earthquake of July 1883, in the island of Ischia. British Association Reports; Read at Southport, Sept. 1883. All these communications were collected together, with others relating to the same subject, and reprinted in a small volume entitled « Notices on the earthquakes of Ischia of 1881 and 1883 with a sketch-map of the isoseismals etc. » which appeared in December 1883.

In conclusion, I am deeply indebted to Prof. Samuel Haughton for kindly undertaking the purely mathematical portion of the work; to Mr. Antonino Patamia for material assistance in publishing it; to Mrs. Lavis for much help in many ways, both during the field investigations and in the preparation of the manuscript. Many thanks are also due to Mr. Nesbitt, for his kind hospitality after the earthquake of 1883; and to the Rev. J. C. Fletcher, Messrs H. J. Galton and Neville Rolfe, for kindly looking over the proofs.

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Naples

May 30th 1885

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CHAPTER I.

Introduction.

Although many observations of seismic phenomena reach us from remote antiquity, yet it is not twenty years, since Mallet gave to the world his great treatise dealing with the earthquake of 1857. In the latter part of 1880, I had been perusing the two volumes forming the memoir above mentioned, and could not but be struck with the ingenuity of the theories and methods of investigation there put forward, and I hoped, as a resident in a very unstable land, to have the advantage of being able to verify if such methods of investigation were really capable of being carried out.

These expectations were soon fulfilled, for on the morning of March 5th 1881 information came to me that, the day before, the island of Ischia had been visited by an earthquake, and that the town of Casamicciola had been destroyed, with the loss of many lives.

The steamer left Naples at 1 p.m. only giving me time to obtain a map, compass, measuring tape, and a few other necessaries, and I depended on good fortune for the rest. On this occasion, the visit to the island was one of curiosity, not of research; but when excursions were made in various directions from the centre of the disaster, the truth of the writings of Mallet strongly impressed me in so many ways, that a desire to carry on the observations in a systematic manner, and in more detail, was developed. After a three days general survey, a return to Naples was made to obtain the materials for carrying on investigations more fully, and for a prolonged stay.

On my return, three weeks were spent on the island, and the following observations on the earthquake of 1881 were the result. More than two years afterwards, about the same amount of time was occupied in investigating the earthquake of 1883. In addition to the above, on various occasions, journeys

were made to Casamicciola between these two dates to verify, or extend, my earlier observations. In consequence of a trifling domestic affair, I left the doomed town only a few days before its final destruction, otherwise, it is doubtful whether this book would have ever been finished, or published in the incomplete state it was left in at that date.

Every house that could be heard of as injured was examined, and a great many uninjured ones passed under observation. If anyone looks at the modern map of the island, he will remark the large number of buildings included in the localities known as Casamicciola, Casamenella, Casamonte, Panella, Lacco Ameno, Mezzavia, Monterone, Speroni, Olivieri, Monte, Bagno, Mandra, Fontana, besides parts of the city of Ischia, Forio, and the towns and hamlets on the S, of the island; and he will understand the labour required to examine all these both within and without.

The result can be regarded as but very imperfect, which is consequent upon many difficulties that cropped up in the course of the work. These were of various kinds; in the first place, the author had no former experience of this or similar work, a drawback of paramount importance; then the necessary instruments were of the roughest kind, for the common reason in such cases. There was also the insuperable difficulty of magnetic perturbations; arising from the large amount of Magnetite irregularly distributed in the lavas and tufas: and it is to this that many of the discrepancies in the azimuths are due. The bosses of trachyte, especially that in the N. W. corner of the island, acted very markedly on the needle. Had a theodolite been at my disposal, much better results could have been obtained, by taking bearings directly from the point of observation, through some known building or natural feature, which, from the smallness of the district, could easily have been made practicable.

In other earthquakes that have been investigated by Mallet's method, each village afforded a number of azimuths from which the mean could be deduced, so that errors were reduced to a minimum. In the present case, however, a false azimuth may depend, on former injuries covered by plaster, imperfections and irregularities of construction, bad foundations, and the geological structure of the district; and it was only in 1883 that compound azimuths could be attempted, and then merely on a limited scale.

The researches of Fonseca, Fuchs, and others, have demonstrated the difference in cohesion, hardness, and density of the different tufas that go to compose the bulk of the island, they being interthreaded by masses of trachyte and allied rocks whose elasticity varies greatly. No one can doubt that these must have reflected, refracted and otherwise modified the vibrations before they reached the surface, so that any two points bearing the same relation to the seismic focus, would be affected in a manner differing very considerably from each other.

In the case of a region composed of stratified rocks, the seismologist can obtain a clear notion of the strike, dip, and other details of structure, and

so check his results; whereas, in a region like Ischia, no definite idea can be had of the structure, more than a few yards below the surface.

The buildings that afford the principal data to the seismologist in the investigation of the Ischian earthquakes, are such extraordinary specimens of architecture, and so complicated in form, that the fissures are in most cases so complex as to be incomprehensible. Many of the houses seem to have come into existence as one or two rooms, and then, as the population increased and the towns became richer from the influx of invalids, room after room was added, generally without any bind between the walls or roof of the old with that of the new. As masonry is the cheapest building material, the terraces and roofs are loaded with massive rubble-work pilasters, or arcades, which have little cohesion and elasticity, but great inertia.

Very few of the houses are rectangular in figure, many being irregular rhomboids, or even polygonal in form. The general arrangement of some of the larger houses is such, that some time is required to become acquainted with the topography of the structure.

We must also consider the roofs, which are usually flat and covered by pumice concrete battened hard (*Lastrico*), resting on coarse chestnut laths, which, in their turn, repose on rafters of the same wood, consisting of small tree trunks barked, and inserted only a few centimeters into the wall, so that, as soon as the house rocked, they were drawn out.

The houses of the poor suffered most severely. These consist usually of one or two rooms, upon which a first floor may be built, which is reached by a heavy masonry staircase outside the building. The enormously thick walls are composed of odd pieces of tufa, collected in the vicinity, which are subangular or rounded in form from the weathering of their surfaces. The larger of these masses are piled up in two parallel planes, without, or with very little, mortar. The space between these is then filled in with loose rubble, and, in rare cases, there may be a suspicion of mortar, but usually not so. The mortar made use of is generally of very bad quality, dependent upon the scarcity of all its important elements. As no limestone is found in the island, all the lime has to be brought from Castellamare or Sorrento, making it very expensive. Good sharp sand, or even good «*pozzolana*», is not easily obtainable. Water is so scarce in the upper parts of the island, that it is often worth 10 francs the cubic metre, as it must be brought up on mule back. As a consequence, the material used might be more correctly described as mud than as mortar.

At all times the central rubble part of the wall has a tendency to push outwards the mortared coats, which, from the inferior quality of the cementing material as above described, have so little cohesion, that at the moment of an earthshock the whole crumbles down. This is aided by the shortness of that part of the rafters socketed into the wall, their touchwood condition, and by the great inertia of the roof with its load of heavy masonry chimneys.

Usually nothing can be learned from buildings of this kind, their destruction being too complete.

We must remember that the island is rarely free from earthquakes, and that many of the houses have been cracked and fissured; which fissures, though plastered over, are points of weakness that open , immediately any movement of the ground occurs.

The accounts given by people who have experienced an earthquake are often of some use, but with the exception of those included in the descriptive part of this work, none were of any possible value. The replies obtained to a question, as to what sort of movement was felt, were often incomprehensible. Some would describe it as subsultory, undulatory, and vorticose, all together; or again, an individual would clench his fists and, making them rapidly approach and recede, would reply « in this way ». When asked from whence came the shock, the reply was always « Casamicciola »; but if conducted into a room, or to the locality where he was standing at the moment of the shock, and then requested to indicate its direction, each point of the compass had a fair share. Some replied that it came from all sides; others were too frightened to remember anything. Some heard a noise before, some during, and most after, the occurrence of the shock. The duration, too, of the shocks was most variously estimated.

The low state of intellect, or culture, of these islanders, is such that rarely can one get a question directly answered, aud even then the description is slovenly and inaccurate. There was still another difficulty; I was dragged every where to see « fearful damage » , which usually turned out to be a dirty crack of ancient date, filled by cobwebs. This arose from the rumour of public subscriptions, and I was supposed to be some surveyor sent to value the damage done to each person's property. At Mezzavia I was besieged by ten or twelve old women, and ran a narrow risk of being kissed all round by them; and, as for the amount of invitations to « try my wine ». Bacchus himself would have been surfeited.

All these difficulties, combined with 13 to 16 hours a day occupied in poking ones way into unsavoury hovels, climbing dusty walls often tottering, and much under a broiling sun, may at first seem of little importance, but really contribute much to make ones work imperfect. This account, however, of the objectionable portion of the seismologist's work in the field is not intended to discourage others from working at such an important branch of terrestrial physics, but rather to prepare them for the same or analagous inconveniences.

CHAPTER II.

Geology of the island.

The researches of Scacchi, Fonseca, Vom Rath, and Fuchs have made us sufficiently acquainted with the geological structure of Ischia for all requirements of the seismologist.

From the writings of these geologists, we learn that this island is an ancient submarine volcanic cone, whose centre is occupied by a large craterial hollow, which has been broken down and denuded away on its southern side, so that the E. N. and W. limits of the crater remain as an irregular serrated ridge, the Monte Epomeo. The drainage of the craterial hollow is carried on by a number of barancos, or, more properly, gorges that flow N. to S. and cut the country of the S. of the island into a series of narrow ridges. Earth movements arriving at any of the villages or buildings situated on these narrow bands of rock, would be modified by the intervening gorges, according to the emergence of the vibration , or the angle the wave-path would happen to make with the axis of the irregularities of the surface.

The main mass of Epomeo, and at the same time the oldest and most important material known to enter into the structure of the island, is the well known sanidinic green tufa. This rock is fairly coherent and uniform in structure, can be easily worked into shape with a hatchet, and is traversed by few jointage-planes , so that as a whole it is a moderately elastic rock in comparison with looser overlying deposits. It is exposed at the surface, for the whole of the central part of the western half of the island. Fuchs, to whom we are indebted for the best stratigraphical study of the island, had demonstrated that immediately overlying the Epomeo tufa we have an irregular deposit of what once was supposed to be a marl, but which, in reality is nothing more than the partially decomposed debris of the earlier tufa. The fact that this deposit reaches high up the mountain, and contains post-tertiary

marine shells, indicates that it is formed of the materials derived from the wear and tear of the upper parts of Monte Epomeo, when not more than its crest rose above the surface of the sea. This so called marl, or more properly decomposed tufa, contains occasional and irregular patches of marly clay, which has been quarried and converted into tiles and earthen-ware during some three thousand years. This deposit as a whole, with the exception of one or two outliers and inliers, forms an irregular band stretching across the middle of the island in a N. and S. direction.

Apparently overlying the last, and covering most of the eastern side of Ischia, besides a band along the S. coast, is a mass of more or less incoherent pumiceous and trachytic tufas, with occasional patches of scoria and abundant masses and bosses of trachyte.

These latter are of very considerable importance to the seismologist, in modifying the earth-movements, in consequence of their irregular distribution, shape, size, and their more or less great elasticity. Some of these masses would appear to be very old, and may have constitued lava streams contemporaneous and intermittent with the ejection of the green tufa which forms the main framework of the island (?).

The majority, however, would seem to be the equivalents of the trachytic tufas, with which they are interstratified. Some are certainly the most recent volcanic products of the island, and have made their appearance in historic times, such as that of the Arso, ejected in A. D. 1302.

The distribution of these masses of trachyte, as might be expected, is very irregular. They form, with the exception of the beach at Maronti and the town of Ischia respectively, the whole of the southern and eastern coasts of the island, and occur as bosses, inliers, and outliers, abundantly on the eastern half of the surface of Ischia. The largest mass, however, forms the N. E. corner of the island and constitutes Monte Marecocco and Zale.

So marked was geological structure in modifiying the effects of the earthquake,(1) that it cannot be passed over without comment. The main portion of Casamicciola rests upon the marine marl-like tufa, which seems to have conducted the vibrations much in the same manner as the earlier green kind. Along the junction of the former with the loose incoherent alluvial matter, which forms a band along the central third of the northern coast, there is a marked contrast in the severity and amount of injuries, according as we examine buildings whose foundations are situated on the one or the other rock. At Lacco, that portion of the town which is built on the solid compact green tufa has suffered far more than the other, or western half, although here, no doubt, we must take into consideration the greater distance of the latter from the

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(1) I allude in general to that of 1883, since the extent of the shock of 1881 was not sufficient to base any generalization upon it.

In alluding to the map, it is intended that that of Fuchs should be consulted.

focus. At Forio, we find Monterone and the eastern half of the town more or less completely destroyed, whereas the remaining portion is only slightly injured, the line of demarcation being very abrupt.

Yet examining the subsoil we discover that the line of separation between the slightly and the severely injured portions corresponds exactly with the junction of the loose, incoherent, alluvial, and the compact Epomeo tufa. It will be observed that the whole of the S. W. quadrant of the second isoseismal of 1883, corresponds almost exactly with the line of junction of the loose trachytic and the solid green tufa. One half of Panza is built upon the former and has suffered markedly less than the other half, built on the latter.

Equally striking perhaps is the case of Barano. The northern part, reposing on the marine marl-like material, has suffered more than that portion whose foundation is on the loose trachytic tufa.

Faiano suffered far more severely than would have been expected from its relative distance from the seismic centre. In part, this was no doubt due to bad materials and the method with which they were united, but much was due to the fact that we are here on the junction of three different rocks, namely: trachyte, trachytic tufa or pumice beds, and the scoria of Cremate. Now it is an old and well known fact that earthquakes produce greater damage at the junction of rocks of diverse composition, owing to the difference in their elasticities and periods of vibration, and also to the partial reflection in the transmission of the vibrations from one medium to another. We should expect, therefore, that the greater the difference of the one rock from the other, the greater would be the disturbance produced.

Two rocks more physically different than trachyte and pumice can hardly be conceived: the mass of one being homogeneous, dense, elastic and practically coherent, the other markedly light, non - elastic, and quite incoherent; but, above all, its mass is permeated by millions of vesicular cavities filled with gas or air. Such are the conditions that exist at Faiano, and what we should expect on theoretical grounds, we find to be fully confirmed by observation in the field.

Let I, R_r, R_l, denote the energies of the incident, refracted, and reflected waves; in the case of Light, or Heat, we have.

$$I = R_r + R_l;$$

and no loss of energy occurs; but in waves transmitted, in solids, liquids and gases, there is always loss of Energy, so that

$$I = R_r + R_l + L,$$

where L. denotes the lost energy. L is expended on pulverising and crushing the two rocks at the boundary surface.

S. H.

The influence of these bosses of trachyte requires special consideration. As masses, we may class them into two groups. The first and more common are more or less flat sheets of rock, quite horizontal, or at the most only slightly inclined, and are old streams of lava that flowed at the surface; the second assume the form of irregular sheets approximately vertical to the horizon, whose strike is variable, and whose upper extremity has reached the surface at some point, and has there given rise to a volcanic outburst and the formation of a cone and crater of which there are so many examples in the island.

Let us consider for a moment the effects of each of these, first, taking as examples the lava stream of Monte Tabor, or the Arso, two good types of the first group.

The wave-path of an earthquake, if issuing beneath the nearly horizontal plate of trachyte at a high angle of emergence, will suffer partial reflection; but the main portion of the vibrations will be transmitted, and, from the refraction suffered, will produce injuries in buildings constructed on the hard rock which would indicate a higher angle of emergence than was really the case—the error being proportionally greater, the greater the difference in the density of the two kinds of rock concerned. The buildings themselves would, in the case of their foundations being built directly on the hard rock, suffer very severely.

As the angle of emergence, and, therefore, the angle that the wave-path makes with the under surface of the rock plate, diminishes, the greater will be the amount of reflection, and the less the transmission of the vibrations, so that where the angle is less than 10.° people and buildings may be quite exempt from any injuries, whilst all around may be destruction. In the case of the lava stream of Monte Tabor, this was remarkably well illustrated in 1883. The cemetery wall, and also a circular building, with a massive dome in Doric style, did not even show any signs of injury, though so unstable to lateral movement that we should have expected them to have been much injured; especially as their distance from the seismic focus is much less than that of the other buildings towards the east, such as the Casa Rotaro, which was practically ruined. The angle of emergence at this point was under 10.° and, therefore, was probably nearly totally reflected.

Should an old lava stream be partially buried by the accumulation of alluvial or other deposits, the condition of things would be altered, for the rock plate would receive the blow edge-on, or nearly perpendicular to its edge face, so that a part of the vibrations would be transmitted and a part reflected, although the angle of emergence might be extremely low. The injuries occurring on the plate might be severe, and at the same time buildings on the tufa near the trachyte mass might indicate the effects of a direct wave-path and a subsequently reflected one. This seems to have been the case with the mass of Monte Marecocco and Zale, although here no doubt

the chief reflection must have been from the stem, or subterranean mass, from which the superficial portion was derived.

Passing on now to the consideration of the second type of compact masses of trachyte, we are met by the difficulty of not knowing their exact form and position; there is little doubt that they generally assume the form of vertical plates, since, where exposed by denudation or otherwise, this form is clearly indicated. In volcanic cones we know that these masses fill fissures which are usually radial to the central axis of the main cone. Nevertheless at the Monte Imperatore some horizontal dykes exist. Such masses as these may produce most remarkable effects in modifying both the emergence and azimuth of an earth-wave, as is well illustrated in the N. W. corner of the island. Also, the fact of the activity of the shock diminishing much more rapidly in an easterly than in the opposite direction, may be due to the presence of three or more such walls of rock as have supplied the craters of Porto d' Ischia (?), Montagnone, and Rotaro.

With regard to the latter fact, the less elastic nature, the intricate interweaving of rocks of different elasticity, resulted in continual reflection and refraction, in addition to the absorption by the loose materials.

The value of a completely incoherent rock, as a material for foundations, was remarkably illustrated at the *marinas* of Lacco and Casamicciola, for the houses built on the beach, (the foundations of which were often licked by the waves), were so slightly fractured that the damage done to them was out of all proportion to their distance from the seismic focus. It is said that all rules have an exception, and certainly that one indicated in the well known parable relating to the building of a house on a rock has one in the case of earthquakes.

Physical configuration had much to do also with modifying the effects of the earthquake. The island of Ischia, from its mountainous character, possesses few level spots, and as a consequence, many houses were built near the edge of a scarp, which was often of loose tufa, and ill supported by revetment walls or other means. As a consequence of this, partial or complete landslips were very abundant, so that many houses and buildings were destroyed from this cause, their foundations actually slipping from beneath them. Numerous fissures occurred in the injured district; but these were always parallel to some scarp edge, and were the result of partial landslip.

There were very few buildings that failed to show more than the effects of one shock. Besides the geological structure, the physical conformation seems to have done much to reflect the wave-paths continually, so as to produce that rotation of objects of which two remarkable instances are those illustrated in Photos. II, XVIII, and Figure 2, Plate I.

My own opinion is, that mountains and hills are subordinate to rock structure and density in their power to reflect the vibrations, although the

case of Potenza and Montemurro described by Mallet (1) has many parallels in the present instance.

The only locality in the island where the earthquake was not felt was the Castello d' Ischia , which occupies the apex of a peak of trachyte united to the mainland by a narrow causeway, so that the upper part of this rock was in the earthquake shadow.

(1) The Great Neapolitan Earthquake etc. Vol. II. p. 355.

CHAPTER III.

Historical review of the Earthquakes and Eruptions, from earliest historic times up to the present.

Fuchs has discussed the question of the early volcanic disturbances in Ischia with so much fairness that I need only give his deductions. From a passage of Pliny (1), and from another of Strabo (2), he concludes that the departure of the Eretrian colony, and the destruction of their city (Ischia?), were the result of the outburst of Montagnone, which was probably accompanied by the formation of the secondary crater of Porto d'Ischia. From contemporary historical facts, this must have been about the beginning of the 11th century B. C.

These fugitives were succeeded by a Syracusan colony, as we learn from Strabo, who seem to have settled at the western end of the island and probably made Monte Vico their citadel. These colonists, in their turn, were driven away by an eruption, which is supposed to have given origin to the trachytic mass of Monte Marecocco and Zale, about the year 470. B. C.

Another eruption is chronicled by Timaeus and Strabo, by whom we are distinctly told that it was preceded by earthquakes; that the earth opened and ejected quantities of ashes; that the sea receded and returned, inundating the land. Fuchs says of this « Here we have the picture of a powerful eruption very faithfully expressed in its particularities; which renders all the account interesting and worthy of belief. » The author I have quoted fixes the date of this eruption in the second part of the fourth century B. C. and at the same time brings forward good evidence to prove that Monte Rotaro is the *volcanetto* then formed.

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(1) Plinii Secundi, Naturalis historia Vol. I, lib. II, Cap. 88.

(2) Strabonis Rerum Geographic lib. XVII. J. Casaubonus recensuit, graece et latine Genev. 1587, lib. XV, p. 171.

Another eruption is chronicled by Julius Obsequens (1); but there are no means of determining from what point it took place. It appears to have occurred about a century B. C. It is also asserted, though on very doubtful grounds, that other eruptions occurred during the reigns of Titus, Antoninus and Diocletian.

In the year 1228 A. D. we are told, on the authority of Richard of S. Germano (2), and others, that 700 persons perished in consequence of an earthquake. From what I can glean from Bonito, the cause of so many deaths seems to have been a gigantic landslip and avalanche of stones. Balaguer however gives more details (3).

In the year 1302 A.D., or according to some in 1301, a series of earthquakes occurred during the months of January and February, which were followed by the opening of a volcanic vent on the N. E. flank of Epomeo. A scoria ring-like crater was formed, and a lava stream of a rather basic, Olivine bearing, trachyte issued therefrom, and after following a course of two miles entered the sea. The crater is now known by the name of Cremate, and the lava stream as the Arso.

Other shocks of minor importance are chronicled, as will be seen by the accompanying table, in A. D. 1659, 1762, 1767, 1796, 1805, and 1812. That of 1796 produced damages that were confined to the immediate neighbourhood of the *Parrocchia* and upper part of the town near Menella, and resulted in the death of 7 persons. This one seems to be the first of that series to which those of 1828, 1841, 1867, 1881 and 1883 belong. There were said to be sixty-two shocks in 1796. At the same time various shocks were felt at Mugello. The earthquake of 1805 was nearly coincident with shocks in the Terra di Lavoro and Sannio.

In 1827 the island of Ischia was much disturbed, there occurring as many as 14 shocks. The strongest was on April 11th, and was felt most severely at Ponza.

The second of the modern destructive series took place on February 2nd in 1828 at 10,5 a. m. the description of which by Covelli (4) is so strikingly clear and accurate, that I introduce the translation here in as

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(1) Prodig.; Cap. 114.

(2) Capecelatro. Istor. della Città di Napoli Vol. I, p. 281.

(3) Anò de 1228 de la venida de Christo, por el mes de Lulio, on Monte de Isquia (E cbentò; y recostandose con suspenascos a los lugares, y casales de su distrito sepultò a setecientas personas de todas estados, que los habitaban; tan violento sue su fuego, como el terremoto a los infelizes Moradores fin tener lugar para la fuga. Denian pensar, que si se dene huir de puestos resbaldizos, tambien en lo mas llano de su Isla estaban en peligro con tantos exemplares enfelizes (F.). *Quantum possumus, nos a lubrico recedamus; in sicco etiam parum feriniter stamus.* Noentraron en lo fagaz, viman en la confianza, y del peligro padecieron el golpe ultimo, que les usurpo la respiracion —p. 89. Los Estragos del tremblor. D. Anastasio Marcelino Uberte Balaguer. 1697 En Napoles.

(4) Il Pontanò (Giornale scientifico) N.° II Naples March 1828.

literal a form as possible, so that the expressions made use of by the author may have their full value (see Chapter IV). This shock was preceded only a few hours by earthquakes in the Romagna and in the Basilicata.

In June of the same year there was another slight shock; as also on Sept. 4th at 9 a. m., which was felt at Casamicciola. Donati mentions gaseous explosions causing much damage, but from researches among the State Archives I can find no mention of them.

The earthquake of 1841 was said to have its centre at Casamicciola; it fissured a few houses.

In 1863 three shocks are recorded; that of January fissuring some walls and determining little landslips above Fango. It is said by De Rivaz (1) that much vapour escaped from the fumaroles of Montecito before, and at the time of, the shock. This is said to have been repeated in April.

In 1867, on August 15th at 12,30 p. m. a strong earthquake occurred, resulting in some damage to Casamicciola, under which, it seems, the focal centre was situated. From the meagre description given of it we should be justified, I think, in classing this as a repetition of the 1828 and 1841 shocks. At the same time a slight earthquake was felt at Naples.

A slight shock happened in 1875, and several occurred in 1880. Signor Coppa, the syndic of Forio, gives the following account of the latter. « From the beginning of July, at Panza, a village on the S. of the island, the wells of potable water are dried up, the thermo-mineral water of Sorgete, which is on the coast, has become fresh, one can no longer see smoke from the numerous fumaroles; the level of the sea has been, and is, much below the normal level. At Forio, which is two miles from the above named village, the wells are in a normal state, only the potable water has become warmer and sometimes turbid during the days of the shocks. The sea, on some days only, recedes more than on ordinary occasions. It is remarked with astonishment by all that the fumaroles have not given out smoke for some time. The temperature of the mineral waters seems to be greater than usual, although the flow is diminished.

« The following shocks were noticed :

24th at 4 a. m. and again at 7 p. m.

25th at 3,45. 4,35., (strong shock), at 5.,9,15, and 11, a. m.

26th at 10 p. m.

27th at 1,30 and at 4,30., a. m.

28th only some doubtful shocks.

Of all these shocks, only that of the 25th at 4.35 a. m. was very strong and it lasted 10 seconds; the others were shorter and not generally felt.

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(1) Description des eaux minéro-thermales et des étuves de l'île d'Ischia. Par F. E. Chevalley de Rivaz. Naples 1859.

« The shocks were not noticed contemporaneously at Panza and Forio; but in the former locality they preceded the latter by a quarter or half an hour. The shaking was sometimes in one place and sometimes in another, often a region strongly agitated by one shock has been slightly moved in another, and vice-versa.

« The strong shock of the 25th was felt in the Ponza islands. At Ventotene a church was seriously injured (1) ».

During the first days of March 1881 earthquakes were felt throughout Italy, at the Lago Maggiore, Val d'Ossola, Alto Vercellese, Valsesia, Biellese, Canavese, Val d'Aosta, and Cosenza. On March 4th 1881 at 1.5 p. m. the whole of the upper part of Casamicciola, and all Casamenella, and Fango were destroyed, with much damage to the surrounding districts, and at the same time 127 persons were killed. As in 1828, the great shock was followed by a number of small ones on March 7th, 16th, 17th, April 3rd, and July 18th, whilst on the continent continual seismic movements were going on.

In March 1882 a slight subterranean disturbance occurred.

On July 28th, 1883, at about 9.30 p. m. a terrific earthquake destroyed the whole of Casamicciola, Casamenella, Fango, the greater part of Lacco, half of Forio, and severely damaged most of the other towns and villages on the opposite side of the island. There were 2313 deaths, besides a large number of seriously wounded. This was contemporaneous with a number of earthquakes throughout Europe, but especially in Italy.

The seismic disturbances of the Italian peninsula in July 1883 are recorded by Prof. M. S. de Rossi thus:—« For some days before the 25th, and the 28th, the microseismic movements in Rocca di Papa together with the microphone in Roma, indicated a great awakening of the internal telluric activity. The earthquakes that occurred on the 25th, at Cosenza and Catanzaro, appear to be the greatest which preceded those movements. »

The great shock was followed by some 14 others that were markedly felt; but when at Lacco and other places, while sleeping at night under a tent, and often with only a blanket between our bodies and the ground, we seemed to feel a constant tremor of the earth.

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(1) All these phonemena are probably due to the season and the high temperature; thermal waters always seem to be cooler in the summer. There are no wells at Panza and the cisterns were dry because the people had exhausted them. In the dry hot air of July all the fumaroles appear to smoke very little, whereas with cold moist wind they expel large columns of vapour; the state of saturation of the atmosphere is the obvious cause. H. J. J. L.

List of Earthquakes and Eruptions in Ischia. (1)

1025 (?) B.C. Eruption of Montagnone (?) and Porto d' Ischia (?) which drove away the Eretrian colony.

470 B. C. (about) Eruption of Monte Marecocco and Zale (?) which drove away the Syracusan colony.

400—352 B.C. Eruption of Monte Rotaro(?), which drove away the Ischians. Preceded by earthquakes.

79—81 A. D. doubtful eruption.

138—161 A. D. « «

284—305 A. D. « «

1228 Great earthquake; 700 killed.

1302 January and February. Earthquakes followed by the eruption of Cremate and outpour of the lava dell' Arso.

1559 Church of Campagnano fell in consequence of an earthquake.

1659 The island damaged by an earthquake that ravaged the whole of Calabria and S. Italy.

1762 July 28-29 th many strong shocks.

1767 Church of Rotaro shaken down by an earthquake.

1796 March 18th 5, 30., p. m. Strong shock. Upper part of Casamicciola damaged, and 7 persons were killed.

1805 July 26th moderate shock.

1812 Near the middle of September, slight shock.

1827 Many shocks. One strong on April 11th..... This earthquake was felt direction N.W. ant S.E. (2) 14 shocks in all. strongest at the island of Ventotene.

1828 Feb. 2.nd at 10,15.,a.m. destructive earthquake at Casamicciola. Some hours before slight shocks in the Basilicata and Romagna.

« Feb 14th a strong shock at Casamicciola.

« End of June, earthquake in the island.

« September 24th at 9 a. m. earthquake at Casamicciola.

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(1) I am indebted in great measure for this list to Prof. G. Mercalli. (I Terremoti dell'Isola d' Ischia. Atti della Società Italiana di Scienza Naturale Vol. XXIV.

(2) An azimuth of this kind is useless unless the exact locality of observation is given.

1834 Various slight shocks.
1841 March 6th at 1.p.m. (??) repeated in 6 minutes; strong shock.
1851 August 14th at 2.20 p.m. Strong shock.....1851 Destructive earthquake at Melfi; Vesuvius and Etna disturbed.
1852 June 7th at 10,35 a.m. Strong earthquake, Casamicciola, Lacco and Forio.
1853 May (?) 10.35 a.m. Subsultory. No damage.
1863 January 30th at 12,30 a.m. very strong shock.....Felt at Ventotene.
« March 22nd. Slight shock.
« April 29th at 6,30 p.m. slight shock.
1864 Oct. 30-31st, night, slight at Forio.
1867 August 15 th 12,30 p.m. Strong earthquake. Centre and some damage at Casamicciola.
1874 January 23rd slight at Casamicciola.
1875 July 13th at 1,30. a.m.
1879 July 24th at 6,45 (?) slight shock.
1880 July 24-28th Many shocks, one very strong,.....July 25 th Earthquake chiefly at Forio and Panza. at Ventotene. The earthquake was felt first and more sensibly at Naples, later and more feebly at Vesuvius.
1881 March 4th at 1.5 p.m. Destructive earthquake at Casamicciola and Lacco.
« March 7th at 12,5 a.m. (after midnight) and another at midday, slight shocks.
« March 11-12th slight shock.
« March 15-16th Midnight strong shock at Casamicciola.
« March 17 - 18th, night. Feeble shock at Casamicciola.
« March 27th———(?)
« April 5th and 6th.
« July 18th 8,30 p.m. rumble and slight shock felt most at Fango.
1882 January. The sea was said to have much receded from the beach.
« March, before the 4th, subterranean agitation; various wells (?) of potable water entirely dried up. A few slight shocks.
1883 July 28th 9,30 (?) to 9,45 (?) p.m., disastrous earthquake, destruction of Casamicciola, Lacco and other towns and villages.
« 10,30 p.m. another slight shock.
« July 29th slight shock in the morning.....July 31st Vesuvius commenced a more active stage, which increased for a few days and continued for some weeks.
« August 1st 3,10 p.m. slight shock.
« « « 4,50 p.m. « «
« « « 11,15 p.m. « «
« « 2.nd 2,30 p.m. « «
« « 3.nd 1,16 or 2,16 p.m.
« much stronger and produced
« slight damage.
« August 8th 10,40 a.m. slight shock.
« « 12th morning « «
« September 4th 10,30 a.m. and again at 10,40 felt at Barano, Serrara and Forio, slight.

1883 September 10th 9,25 , slight shock at Casamicciola.

« « 11th midnight. Strong shock. Shook the revolvers of the Carabinieri off the nails on the walls.

« « 21st at 5 a. m. Slight at Casamicciola.

« « « at 10,30 a. m. slight at Casamicciola.

October 14th two slight shocks at Casamicciola and Forio.

CHAPTER IV.

Notes on the earthquake of Ischia, that occurred February 2.nd 1828; by Signor Nicola Covelli of the Acad. delle Scienze di Napoli (1).

« Southern Italy seems alone to remain the theatre of the grand revolutions of nature. The volcanoes, that at one time devastated the whole of Europe with their torrents of fire, ceased burning in Scotland, Sweden, along the Rhine, in the Auvergne, in Hungary, the Tyrol, Northern Italy, and in Greece, thus abandoning the burnt up ground to the industrious hand of man, which has converted it into fertile fields and populous cities. But here, the natural forces, always retaining the same vigour, prolong those terrible catastrophes which in other places are entirely finished. Vesuvius, Etna, and Stromboli renew their eruptions from time to time as if they were outlets destined to drain from the interior of the globe the immense quantity of matter that an invisible but powerful play of forces has collected during many years: thus, in 1301, a current of lava was vomited forth in the island of Ischia; and in 1603 (2), by a great and instantaneous eruption, a mountain was formed in 24 hours in the still smoking ground of Pozzuoli. Meanwhile the earth does not yet seem to be settled, but shakes frequently first in one place, then in another, producing damage and ruin. And so frequent are these terrible catastrophes happening to us, that earthquakes, and volcanic eruptions, which, if only named in other countries, inspire terror, are to us familiar natural phenomena, to which we are almost as indifferent, as the inhabitants of other parts of Europe are to eclipses of the moon and sun.

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(1) Extracted from. « Il Pontano » N.° II. page 82.
(2) It should be 1538.

« From 1805, the epoch of the terrible earthquake which ruined many cities of Sannio, which extended itself to the extremities of the kingdom, how many other frequent shocks were felt here and there, first in one province, then in another , and how many we can count of late years felt in this capital! In the year 1827 one can count 14 of them in the Island of Ischia , the strongest of which took place on April 11th, whilst my colleague, Signor Lancellotti , and myself happened to be on the island for the purpose to analysing the mineral waters.

« The frequent shocks in that locality showed clearly that they correspond to the same centre of concussion, having taken place at a distance more or less great : such was that of April 11th , which appeared to come from the island of Ponza where the shock was more energetic than elsewhere. But these frequent and slight oscillations of the earth of the island , seemed to be so many warnings of some terrible event, which unfortunately did not keep us waiting long (1).

« On the second day of February of this year 1828 at 10, 15 a.m. a strong earthquake so shook the ground of the island that it seemed as if it would sink into the depths of the sea. The shock was announced by three powerful blows coming almost vertically , from below upwards , and successively, the one after the other at an interval of about three seconds: so that it seemed that these took place like blows struck upon the upper walls of the subterranean cavities of the island. These triplicate successions sounded like so many cannonades starting from the interior of Epomeo : only more like a deep roar resembling the explosion of detonating powder. The subterranean noise was very audible at the marina of Casamicciola, of Lacco , and of Forio : little was heard in the interior of the island , and in the actual places maltreated by the shock. We only distinguished a single blow , as if given under the vault of the house, by a ponderous hammer : as at this first sign , we hastened to take refuge in the neighbouring garden. What a spectacle presented itself when we turned our eyes to Casamicciola ! A dense cloud of dust filled the entire village , raising itself gently in the air, and appearing to resemble that column of smoke which announces an eruption of Vesuvius. Amidst this dark cloud , the confused cries of hundreds of the inhabitants rose up to heaven, the awful effect of which , together with the shock already past , inspired our dizzy minds with terror, and seemed to display the horrible spectacle of a fiery mouth opening itself a short distance from us.

« Tranquillity having returned, we directed our vacillating steps towards Casamicciola. With what security could we walk in the interior of the village, when from time to time the ruins of the fallen houses, unsteady in

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(1) The whole of this paragraph is very obscure in the original.

consequence of the large fissures, were giving way under their own weight, and falling of themselves. And from the piled and confused ruins issued the lamentations of the victims calling for help. Here unfortunate beings half buried, struggling to extricate themselves; and there, upon the confused ruins, an old mother escaped from death, lifted up to heaven her lamentations for the children buried beneath the stones of their house. At the moment, the miserable inhabitants did not flee to save their lives, but, love smothering the feelings of fear, one saw the mother go away crying and dazed searching for the son, the husband for the wife, the brother for the sister, friend for friend, relation for relation, and these became victims of the crumbling houses. At the crushing of the walls as they fell to the ground, one heard the lamentations of the dying, the groans of the wounded, the screams and the cries of the people who escaped from the catastrophe: and from every side there were only tears, sighs, terror, flight, uncertainty, confusion, and despair.

« These heartrending episodes had scarcely arrived at the foot of the throne, when they moved the feeling heart of our Sovereign and his august consort. The *Sotto-intendente* of Pozzuoli, the brave Count Carraciolo-Melissano, was sent the following day to join the good General Tanchi who happened to be in the city of Ischia, and both, with intrepid spirit, penetrated amongst the ruins of the destroyed Casamicciola, and took those measures that the moment required. On the 4th, H. R. H. the Duke of Calabria dispatched one hundred excavators to the island, who immediately set to work to disinter the victims of the earthquake in one part, in another to pull down the houses that threatened ruin, or to prop those which could still stand. As a consequence of this ready assistance, some that were buried under those ruins were safely extricated, and rescued others who from necessity remained beneath the illsupported habitations. Those who had no longer roof or means of subsistance were charitably lodged in the vast premises of the Monte della Misericordia, which in another season serves to receive those, whose chronic infirmity urges them to try the effects of the salutary waters. Besides, the pious Monarch afforded much help to the indigent, and he distributed suitable subsidies, in order that the houses of those people who had no means whatever to reconstruct them might be rebuilt. In consequence of these munificent liberalities, which mitigated to a certain extent the misfortunes of the islanders, they have returned to a calm state, keeping alive in their minds the memory of the terrible forces of nature, and in their hearts stamped the devotion and the generosity of our magnanimous Monarch. »

II

While this help was being afforded by the hand of the government, having gained our composure, we commenced to visit the localities of the island, from the point where the shock was strongest, to where it was hardly felt. *The ground most injured was not precisely the region of Casamicciola, but that which lies between the district called Fango and that known as Casamenella , situated to the west of Casamicciola , and a short distance from it* (1). There, not only very many houses fell and the rest were badly injured, but there was not a bank of earth which had not crumbled; and all the walls without mortar (*a secco*) which the natives call *paracine*, which serve to enclose and support the earth , were totally overturned , and so violent was the shock that not even those of only four or five palms high remained standing.

« The first accounts of the country people made one believe that at Fango the ground had opened and given forth the vapours of bitumen and sulphur. But nothing of this statement we found to be true after having visited the locality step by step. The openings in the ground were nothing more than little cracks which showed themselves alone on the margin of earth banked-up or sustained by walls, the result of such walls having moved from the perpendicular. Such fissures did not show themselves in flat and even ground. They did not exceed the length of 15 to 20 feet, and the width was not greater than an inch.

« The blow which was struck between Fango and Casamenella did not communicate the vibrations equally to every part. One would say this was directed obliquely from below upwards in the interior of Epomeo by a line nearly vertical and inclined from the west to the east, that is from Fango to Casamicciola which suffered the shock direct: which shock reverberated towards the north from Fango and laterally to Lacco , it then reflected itself in the opposite direction from east to west towards Forio. In fact the region of Fango, Casamenella, and Casamicciola was destroyed; so that one would call the blow *direct*: the region of Lacco was only injured, the habitations being simply lesioned, so that one would say that the blow had acted by *contre-coup* (2) but laterally; whilst the country of Forio, which has suffered much less than that of Lacco, received what one would call a shock by *reverberation* but in an opposite direction.

« Besides the centre of vibration in the district of Fango, another less powerful centre showed itself in the locality of Fontana; this made itself felt more heavily than in surrounding localities; as if another centre of movement

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(1) The italics are mine. H. J. J. L.

(2) The authors words are « per urto ». The exact signification is not clear.

had taken place from that part, independent of the former. This locality lies on the south side of Epomeo, diametrically opposite to Fango, but more elevated and exactly on a line drawn from N. N. W. to S. S. E., so that in this case it seems that in the interior of the mountain there must have been a *contre-coup* derived from the corresponding point at Fango, reverberated to the corresponding point at Fontana, rather than from a blow direct and independent of the first.

« This strong earthquake, by which an entire village and many country houses were razed to the ground , and which seemed as if it would have sent Epomeo into the air, not only acted with very unequal force on the island itself, but had not even the power to extend beyond the limits of the same. the vibrations not being transmitted to the neighbouring island of Procida. or to the not far distant continent, where no one noticed the slightest movement.

« Nevertheless, contemporaneously, the same morning, the 2nd of February, sensible shocks were felt in the ground at S. Severo in Puglia, and on the night of the 2nd and the 3rd of the same month, Imola, in the Roman States, suffered a slight shock. This indicates that these effects were not derived from the same cause and the same blow.

« From these facts we conclude that dreadful earthquake has limited its effects to the island of Ischia, and manifested itself at the surface of the earth of a small portion of the same , with those injuries which we have above described.

« The dead did not exceed the number of thirty, and the wounded did not reach fifty. No other phenomena worthy of observation took place before or after the earthquake. The sea was quite calm previous to the occurrence and retained the same tranquillity directly after, and during all the day. The same can be said of the air, the calm of which was not interrupted during the day, and which offered no phenomenon worthy of registering, either antecedent to, or after, the shock.

« The meteorological table, which includes the observations made by me on the island from January 25th to February 14th, that is to say 7 days before the earthquake and 11 days after, can be compared with the other table which exhibits the observations made by signor Nobile in the Royal Observatory of Naples for the months of January and February; and thus it is to be seen that the state of the atmosphere continued its usual course in Naples as well as on the island ; except that the barometer , towards the middle of January, showed an unusual maximum elevation of the mercury, which had never been verified in the preceding six months. Our illustrious associate, Archdeacon Cognazzi, who has diligently observed the state of our atmosphere , has (in a learned memoir read before the Royal Academy of Sciences) with much ingenuity shown the relation of the meteorological variations to the cause which had this winter brought unusual diseases.

III

« Such an energetic commotion limited to this island alone, and directed against the side of Epomeo, which appeared as if it must open at that point, must have caused much damage in the interior of that mountain , whose many eruptions lead one to believe it must be hollow; the more so because large subterranean chambers retain sufficient heat to warm the thermal waters and the numerous fumaroles which smoke here and there on the surface of the soil.

« The observations upon the thermal state of the island after the occurrence, were of the greatest importance; to sound, to a certain extent, from what depth the blow came, and to prognosticate approximately the force of succeeding catastrophes which might take place.

« To establish the difference between the previous conditions of the thermal waters, and that in which they were found afterwards, it is necessary here to indicate the results of the thermometric observations made last year by my colleagues and myself: that is, those of the Cav. Monticelli upon the fumaroles, and those which we, in conjunction with sig. Lancellotti, made on the thermal water.

« The thermal region of the island does not at the first glance seem to be very extensive. One may say that it occupies exclusively the northern part, and is confined in a zone comprised within a line drawn from E. to W. that is from the city of Ischia to Forio, which terminates at the northern shore of the latter. The only place not included in this zone is the district of Citara, where the water and the ground possess a very high temperature. The general reservoir of the heat of the island seems to exist in the interior of Epomeo , whence the thermal waters are derived : and upon the slopes of which , at a certain height , the temperature is much higher than that of the low regions near the sea. In fact in the upper regions , comprised between 468 and 500 feet above the sea level, the temperature of boiling water, that is 80° R., is exhibited by the mud called Bobò, and that of 78° R. in the fumarole of Montecito. The heat diminishes in the lower regions, since at the height of 163 feet, this descends to 50° in the water of the Rità; at the altitude of 120 feet, it is 50° in the water of Cotto or Fontaniello; and at 108 feet one finds 55° in the water of Gurgitello. The maximum temperature at the sea level does not exceed 54° and then only in the water of Capitello, and in the sand of Castiglione; whilst in the others, as Citara, S. Montano, and S. Restituta one finds it between 40° and 50°.

« It would appear therefore that the thermal waters become heated in the interior of Epomeo, at the altitude of about 500 feet higher than the level of the sea (1).

(1) The author Signor Covelli seems quite ignorant of the springs of Maronti, which have a temperature 101° C. and are situated at the edge of, and beneath, the sea. Besides, there are many others on the other side of the island which are not included in a line from Ischia to Forio.

« Having at present, in this manner, a knowledge of the thermal state of the island, I hasten to compare it with the table of the same observations which I had repeated in great part at the above mentioned localities seven days before the shock , and only established that slight difference which depends on the thermometrical state of the season. Therefore the thermal waters and the fumaroles of the island gave no sign that could announce the grand convulsion of the earth. But , after the terrible shock, we were certain of some great change in the temperature and in the quantity of the springs , and vapour of the fumaroles: since the blows accompanied by subterranean thunderings were of such force, that they seemed to be delivered but a little distance from under our feet. And our suspicions became a certainty as regards the water of the Rita, which is the nearest to the centre of vibration. But to our surprise, the stufe of S. Lorenzo, visited the evening of the 2.nd, that is eight hours after the earthquake , did not show any sensible change, either in the temperature or in the quantity of its vapour. The water of the Rita was found the day after at 48°5 R. the air being 10.° exactly as it was the day before the shock : last autumn this water was found at 48.°9 the air being 18°; in the preceding summer 49.°5 , the air being 22.° The quantity of the water of the spring , before and after the shaking, showed no appreciable variation.

« The temperature of the higher regions of the mountain, at the localities nearer the centre of movement like that of Montecito and Frassitelli , one found as they were in the autumn. And that of the middle region, that is (1) Spuma Pollastri of Gurgitello, of the Tamburo, Cotto, etc. offered no sensible variation. Whilst the baths of S. Montana , S. Lorenzo , Lapitello, etc. presented no other change whatever than that dependent on the temperature of the air.

« The effect, therefore, of the great earthquake of February 2nd, which caused so much damage to the habitations , and spread so much alarm in the island, is not the result of the vast cavities which heat the thermal water and feed the fumaroles of this locality. And this fact is so much the more singular , inasmuch as the blow was particularly struck in the thermal region of the island, as if there was an internal and intimate relation between the cause of the shaking and the productive cause of the heat. But the source of the heat, which sustains itself for so many centuries in the interior without apparent cooling , is much higher relatively than that from whence the actual disturbance came, for this seems to be seated at a very great depth. And if but for a little these two localities had been near each other, great alteration would have occurred in the reservoirs of the waters and in the fumaroles: it seems therefore the explosion took place at such

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(1) Spenna Pollastri.

a depth, that its vibrations arrived in the interior of Epomeo much enfeebled, which ought to have suffered no sensible alteration.

« These are, gentlemen, the few observations presented to me by the ground of the island after the terrible commotion which it underwent. From these one can come to no conclusion as to the cause of the violent and instantaneous phenomena, which still remain in the most profound obscurity. Still the vulgar mind, renewing the dreams of physicists of the past century, repeats that such disturbances depend on electricity, which, accumulating in the earth or in the clouds, discharges itself violently to restore equilibrium, producing thunder, lightning, and the earthquake.

« In finishing this short notice, I concluded that this terminated the catastrophes of the island. But another strong shock happened here the morning of February 14th, twelve days after the first, in consequence of which, many houses, already weakened, have fallen in the vicinity of Casamicciola.

« Another phenomenon manifested itself in our district, after many shocks it has suffered, especially in the past year. Vesuvius, on the 14th of this month (March 1828), at 2 p. m., commenced its eruptions after a silence of six years. A mouth opened itself in the centre of the crater, which last night and the night before frightened the inhabitants of the neighbourhood of this volcano, with the noise of its strong detonations. This new mouth limits itself at present to ejecting scoria and pieces of lava so soft that the Vesuvian guides make impressions in it with money.

« This small eruption appears to have been announced by the repeated shocks of our district which have an entirely volcanic origin, as indeed the experience of so many centuries teaches us ».

CHAPTER V.

Field observations of the earthquake of March 4th 1881

As we land from the boat we are struck by the apparent absence of serious damage to the houses in view, which here are ranged in a line parallel to the sea front, with the church of S. Giovanni in the centre. After careful examination of each house, only a few fissures were discoverable: these occurred in no uniform direction, and in fact no deductions could be drawn from them.

1. (*) Following the esplanade eastward, just before the road crosses the little beach of the Vallone Ombrasco, a small house on the right side of the road is fissured nearly N. and S. giving roughly an E. and W. path. As the fissure runs through two window openings on one side only it can hardly be depended upon.

Next are some houses which were apparently uninjured, or, at the most, have only faint cracks in the plaster.

2. Farther on, after we have passed the turning to the right, we see the villa Maresca, a large pink building, standing back on the northern side of the road. Its longer axis runs about 37° N. of E.: fissures cross the house at right angles to it, and they are more open at the S. W. end.

Close in front of the house, is a double iron gate (Fig. 1, Plate I), which is parallel to the face of the building. Each half of this double gate is supported below by the continuation of the outer frame-bar being prolonged downwards and inserted in a socket in the plinth stone; the upper end of the same bar is inserted, and revolves, in an eyelet-like piece of iron which

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(*) The numbers at the commencement of a paragraph correspond to those appended to the azimuths and in the diagram of *emergence* angles (Plates III and V).

projects from, and is cemented into, a stone pillar. The pillar is composed of two squared blocks of trachyte, the upper being about half the height of the lower, apparently fitted together without any cement. It is to the upper or smaller of these two stones that the eyelet is attached. On the opposite side, that is to the S. W. of this pillar, it has built against it a plastered rubble wall with considerable adhesion to the stones.

The tendency at all times would be for the half gate to pull the upper stone towards itself or to the N. E., which would be rendered very easy by the ground vibrating in the plane of the gate.

This has really occurred; the upper stone has torn away its connection with the wall, and has slid 3 centimeters in the direction of the gate, which therefore would give a wave path parallel to the plane of it, similar to that derived from the house.

The displacement is in the same direction as the propagation, but this will be seen to be of easy explanation. The first semiphase would be forward from 37 S. W. to 37° N. E. and would be expended in overcoming the strain which the weight of the gate exerts at all times in the opposite direction ; and, even supposing it to have been more than necessary, the wall against which the pillar was built, and which supports those blocks on the sides towards the seismic vertical, must have acted the part of a buttress. In the second semiphase of the wave quite a different effect would be brought about , since the inertia of the gate and stone would have a tendency to make it fall to 37° N.E., that is, opposite to the direction of motion in the second semiphase and in that impressed upon it by the first semiphase. The little resistance that would be offered by the adhesion of the upper stone to the wall, and the friction between its base and the stone on which it rested, would do little to prevent its shifting on its support a distance of 3 centimeters. In all probability it would have gone farther, but this half of the gate met its fellow, as they were closed at the time, and thus prevented further motion. The opposite pillar was not disarranged, as it was more strongly built, and had a greater amount of adhesion to its companion wall.

The garden, of which this gate was the entrance, lies between the house and the road , from which latter it is separated by a revetment wall capped by trellis work, except at one point. There the trellis is replaced by wrought iron railings, constructed ladder fashion, which are inserted at both ends into two short rectangular plastered rubble pillars. The plane of this boundary is nearly parallel to the axis of the house and gate. Of the two pillars, the S. W. one is torn across about its middle and the upper fragment has shifted to 37° N. E. as if pulled by the upper bar of the railing.

On the pillars were two flower vases both of which fell; but some officious person immediately replaced the fragments, and I was unable to gain enough accurate information to study their projection. The garden itself is some three metres higher than the road and supported by a wall on which the pillars and rails rested. If the line of propagation had been at

any considerable angle with the wall, the latter would have rocked and separated from the earth it supported, so as at least to leave a fissure between the two; of this, however, there were no signs.

From these different observations in the same locality, remarkably confirming each other, we obtain a wave path that must be very near 37° N. of E from 37° S. of W.

On the same side of the road and a little further on is a large house at a place called Perrone. The proprietor, whose name unfortunately I cannot decipher from my notes, gave some interesting information. He says « I « was standing on my balcony (this faces Casamicciola) admiring the scene, « and remarking the picturesque position of the town, when I felt the house « rock, feeling at the same time as if something was rolling along beneath « the ground. This movement was accompanied by a sound like this.

« Boob, boob—boob——boob————boob————boob.

« Both noise and movement seemed to come from Casamicciola. The shock « did not frighten me as it was not very strong, so that I did not move « from my position. In a few seconds, in the distance over the town arose « a terrific cloud of white dust, so that I imagined the town on fire. The « dust however soon cleared away, and I knew what had happaned when « I saw the coloured wall papers (carta di Francia) on the ruins. I felt « hardly any, if any, subsultory movement, but as I lent upon the balcony « rails, I was alternately pressed against them and then drawn away. Nothing « fell in the house ».

From the peculiar sensations of the proprietor, and from the position of the balcony, we must conclude that the wave path was low and nearly at right angles to it and therefore corresponding with the last observations. This is confirmed by the few cracks, which however were small and much modified by heavy arcades, and irregular arrangement of doors and windows.

Where the road skirts the base of Monte Tabor, enquiries were made and resulted in such answers as « piccole cose « piccoli rumori » little things, little rumble.

3. In answer to questions at the stufa of Castiglione, no apparent change in quantity or temperature of the vapour had been observed at the time of, or after, the shock. A thermometer placed in the hole from which the vapour issues gave a maximum temperature of 54° C.

The occupants of the neighbouring houses which were uninjured said the ground moved from E. to W.

Descending to the beach the ruins of an old thermo-mineral establishment are encountered. There the once renowned Acqua del Castiglione issues beneath the mass of trachyte on the foreshore; in an open pool of the pure water it had a temperature of 65° C, and by digging into the shore sand 75° C was obtained; in fact the sea for some distance from the shore is steaming and quite hot to the immersed hand.

Where the road crosses the slope of monte Rotaro, at a house on the

S. side, the shock was feebly felt, but glasses in a delicate position did not fall, nor was any damage done.

A little beyond this, and higher up the side of the old cone of Rotaro, is a place called Cercola, which showed a few and irregular cracks in the plastering, which may have existed before.

I may here mention that as soon as the people of the injured district heard of the distribution of money for repairing damages, they devoted their time to hunt up every crack in the walls and make much of it. In many cases they believed they had discovered new ones, whereas their attention was only now directed to those already existing.

After passing a turning back to the right, and on the slope of Montagnone, only faint lateral movement was felt.

4. At the four cross roads a lateral E. and W. movement was observed. There was a faint crack that has a suspicion of being old.

At the village of Bagno no damage was done. In a conversation with the Chemist and others, I gathered that a faint subsultory, followed by a more distinct lateral, movement in an E. and W. direction was felt. The shock of the following Wednesday was felt and described as a rumble. At the new thermo-mineral water establishment I got, at the source of the water, a temperature of 49° C.

In the city of Ischia (as far as my memory goes) about one half of those asked replied that they had felt the earthquake. It was generally described as undulatory. The movement was accompanied by a noise like the rumbling of carriages. There were only a few cracks to be seen, most of which are old ones slightly opened.

Taking the road that leads to Campagnano, after a quarter of an hours walk, we arrive at a branch road, and close by are some houses marked on the map by the name Capella, where nothing whatever was felt. At a house some distance beyond, on the opposite side of the way, there are a few (suspiciously old) cracks. From here to a place called Vico, out of many people asked, only a few replied that they felt the shock faintly.

The village of Campagnano is situated on the crest of a ridge whose line of axis, if continued, would pass through Casamicciola, and therefore a vibration travelling along it parallel to its axis, we should expect to be felt but feebly; which was in fact the case. Beyond the church a group of houses known as Gradone, stands on the spur near, at right angles to the first; and therefore, from their position, at the end of a short pendulum, they would be expected to feel the shock distinctly, which was the case with the first, as well as with that of the following Wednesday. One woman fell down. A priest described the movement as lateral.

Commencing the return part of the loop-like journey by taking the road to the hamlet of S. Antonio, where I heard that a faint lateral movement had been felt, but farther on, close to where the aqueduct crosses the valley, all the inhabitants said they felt the first shock and that of Wednesday very

distinctly. At some cottages at the opposite or W. end of the aqueduct the people declared they did not feel the first, but that that of Wednesday was distinct enough, causing the pictures on the walls to move. Unfortunately the mental powers of many of these people render their assertions as to direction and other particulars quite unworthy of notice, for a sharp cross examination shows that they answer for the sake of answering. All accounts therefore of direction etc. given in this paper are chosen from a great many investigations, or are only those of intelligent members of the Ischian population.

About midway between the last point and the bifurcation of the road, at a small cottage on the right, both shocks had been detected, but that of the 4th strongest.

At the commencement of the second aqueduct called Fiaiano, only that of March 4th was felt, but an individual thought he had noticed the second faintly. Towards the end of the aqueduct, two walls, built without mortar, of loose scoria (and having a direction nearly E. and W.) showed a fall to the N., whilst a house near had faint cracks running E. and W. The first of these examples I consider of little importance, as very little motion of any kind would shake down such walls. The case of the house seems somewhat difficult: but it was probably due to bad masonry or some unkown local modifying influences. Some people here felt both shocks; others, neither.

5. The house marked Maisto on the map, suffered rather severely; its fissuring gives a path from N. W. to S. E.; and this is as near an estimate as could be made, owing to the irregular plan and construction of the building.

The Casa Rotaro, that lies in the little triangular space formed by the slope of Epomeo and the cones of Rotaro and Montagnone, was not damaged, although both shocks were felt sharply.

From this place to the town there are hardly any houses.

In this journey it will be observed that, as we recede from Casamicciola, the intensity of the shock gradually diminished; that the subsultory or elevatory sensation was gradually replaced by the undulatory. The latter itself soon became extinguished, until at Ischia and along the road to Campagnano many people did not even feel the undulations at all. On the contrary, in the return journey from Campagnano towards Casamicciola, the effects are observed to again increase as we approach the town.

Let us now direct our attention to the district which lies between that just described and that where the shock exhibited its greatest activity, or, in other words, the eastern part of the mesoseismal area.

Taking that turning to the right spoken of as passing before the Villa Maresca, we soon arrive at a group of houses and the church of S.^{t} Pasquale. This traverses the eastern outskirts of Casamicciola.

6. In the house belonging to Signor Nicola Vanella, there were a few cracks, but none that would give any data. In one room stood a buffet or

glass-fronted cupboard with folding doors, containing on its shelves many wine-glasses etc. The doors were loosely shut and faced to the W. S. W. The movement resulted in the doors flying open and the glasses falling forward on to the floor. This would give a wavepath somewhere near W. S. W. to E. N. E. Against the same wall, that was backed by the buffet, was hung a small clock, whose pendulum would vibrate at right angles to the line of transmission obtainable from the first observation. This had, as would be expected, stopped. The proprietor felt the shock as subsultory and undulatory, and from W. to E.

7. A little beyond is the chapel of S^{t}. Pasquale, which faces nearly 15° S. of W. The front part of the wall supporting the bells had fallen forward to the W.: the fissures in the building show no regularity. This, therefore, gives an approximate path from 15° S. of W.

8. Rising between the church and Casamicciola is a little collina, on which are situated the two large buildings composing the Palazzo Balsamo. The entrance is some distance further along the road. We pass through iron gates up a grand drive, flanked on both sides by high walls strengthened at about every four or five meters by a pillar, which supports a large terra-cotta flower vase. All of these vases were slid on iron spikes in the wall, and only one had been forcibly broken off at the waist and had fallen to the W.: but the pieces were unfortunately carefully piled up in a heap, and the ground smoothed. All the pillars are fissured near their base, and give very roughly an E. and W. path. Both the great buildings afford similar data.

9. The Ospedale della Misericordia is a vast irregular building giving a problematical E and W. path. The face of the great clock in the court yard lies in a plane W. and E. and (I am told) the pendulum vibrates parallel to the face. It had stopped at 1. 5 p. m.

10. A small street here turns up towards the group of houses called la Tresta which lie along the S. E. slope of the « vallone Ombrasco ». This is altogether a poor and very irregularly built neighbourhood, and gave fissures running nearly N. and S. and greatest towards the W. The sensations of the inhabitants correspond pretty correctly with the assumed direction. They however declare they felt two quite distinct, but rapidly consecutive, shocks. The second may have been a reflected one.

We now follow the lane that leads to Olivieri, which quarter is crowded with houses along both sides of the roadway, and especially the western. There, hardly one is not severely fissured; the complicated jumbling together of arcades, pillars, balconies, turrets, chimneys, walls, etc. renders it quite impossible to find any order at all in the fissuring. It would seem that the houses, from their different inertial values, rocked with different periods, thus tearing apart from each other; so that all that now remains is a group of standing but perilous walls. From the impossibility of getting a general view of the injuries, I was unable to obtain any approximation to a result

of wave path azimuth. I do not however doubt that, with more experienced observers, it would have been possible to see order where I saw disorder.

Returning to the main road again, inquiries were made at several of the principal thermo-mineral establishments.

At the Stabilimento Manzi, the man who has charge and management of the baths declares that there was no change in the water before, at the time of, or after, the earthquake. At the Stabilimento Belliazzi the same negative information was obtained; when I mentioned that the newspapers reported the water to have boiled at the time of the earthquake, the employé treated the statement as a piece of invention. At the moment of the shock, I should doubt whether even an enthusiastic seismologist would remain under a roof or near a wall, with a thermometer in his hand, to watch changes in the thermal waters.

These negative statements were confirmed at the Stabilimento Piesco.

11. A house between these two last establishments, which themselves are uninjured, has fissures across its longer axis, that is from E. N. E. to W. S. W. which gives a wave-path from N. N. W.: as we shall see, much too N. of the seismic vertical.

Farther on, near the Bagno Fresco (marked on map) and on the slope of Epomeo, the houses have fissures running E. and W. with a fall to the N. which would give a N. and S. wave path, possibly due to their position on the steep mountain side.

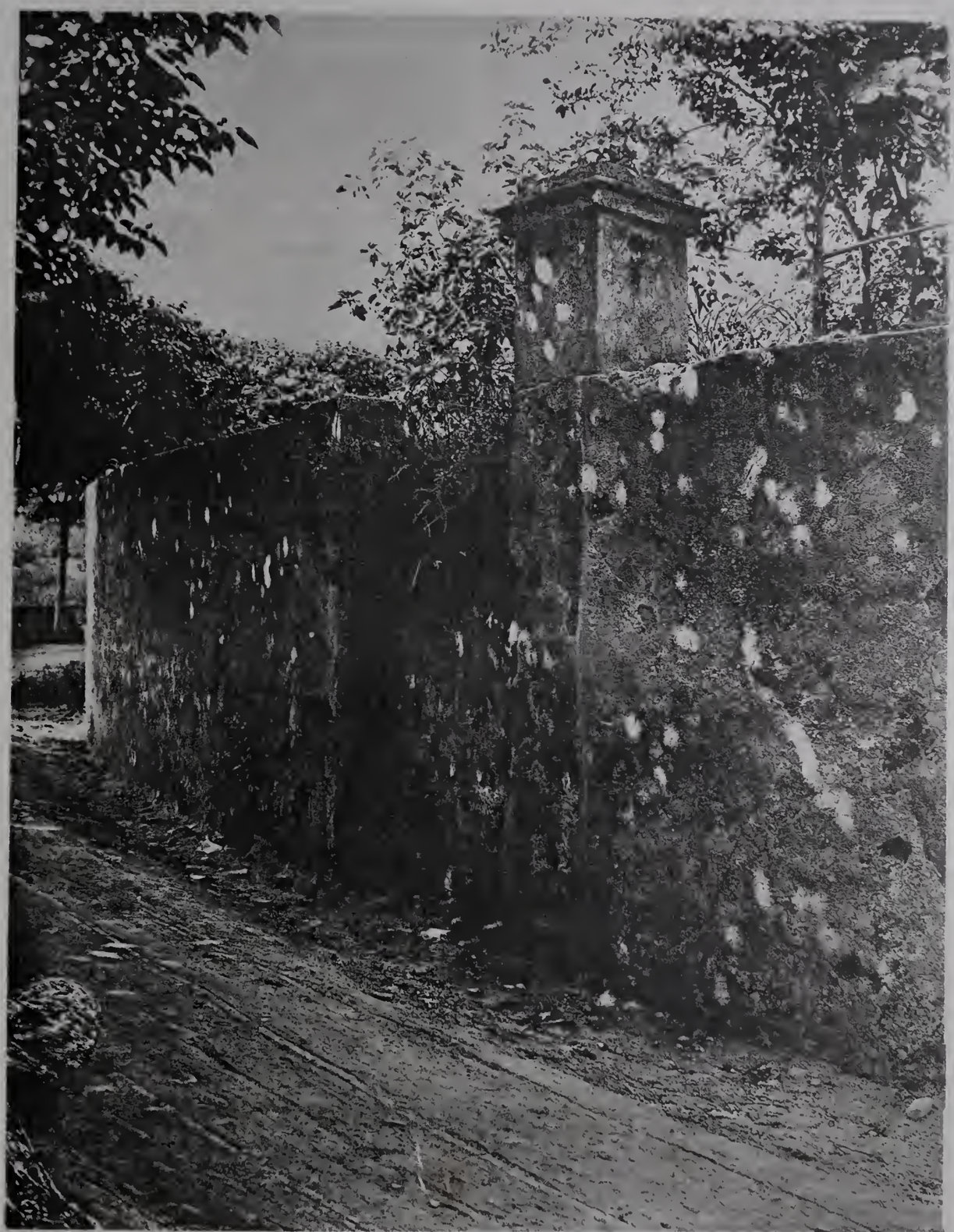
If we now follow the road that leads us up towards the Hotel Romaine and the Villa Barbieri we find our way lined by severely fissured houses, the damage to which increases in severity as we advance towards the town. Passing round the back of the above villa let us take the new zigzag road (not on map) called Via Roma, that leads up to meet the Via Sassola.

12. Close behind the above mentioned villa, and on the opposite side of the road, was an irregular, arched, ashlar wall of a house in construction with no roofing on and quite new. This gave a path coming from some 15° N. of W.; which, however, from the peculiar shape of the building, I feel inclined to accept with caution.

As we proceed up the road nearly every one of the square rubble pillars on each side of entrances has fallen; only two, however, were of a nature to give any data, as most were reduced to fragments in falling.

13. Higher, however, at a point where the road runs nearly N. N. W, and S. S. E. were two new pillars (see Photo. II, and Figure 2, Plate I) that flank a blank gateway. For about two thirds of their height, on their outer sides, they are attached to the garden revetment wall. The space that should be occupied by the gate is filled also by a wall somewhat lower than the main one. On the side opposite to the road is a garden., the level of which equals nearly half the entire altitude of the columns, so that the inner or W. side of the wall is supported by earth, whilst the E. is nearly clear down

PHOTOGRAPH II



H.J.J.L. Phot. Fototip. F.lli Doyen Torino.

Blank gateway in the Via Roma, Casamicciola. The photograph shows both columns broken off, one has fallen, whilst the other has rotated on its base.

to its foundation, forming the road boundary (Fig. 2, *B.*). (1) The southern of the two pillars (*a*) was fractured 22 centimetres above its junction with the wall, and fell in a path nearly due W. Its northern fellow (*b*) was fractured on a level with its junction with the wall, but did not fall; rotating only on its base (*D*).

Applying the formula (Mallet. ibid. p, 128. Vol. 1).

$$V^2 = \frac{4g}{3} \times \frac{\alpha^2+\beta^2}{\alpha^2} \times \left\{ \sqrt{\alpha^2+\beta^2} - \alpha \right\} \text{VI.}$$

we have, reducing the metrical to English measures

V = 6.926 feet per second. (Horizontal velocity)

The result however is less than the reality, for no account has been taken of the resistance offered by the mortar.

This case is that of the overthrow of a *solid rectangular parallelopiped*

α = altitude = 69.5 c = 2.28 ft

β = base = 57.0 » = 1.87 »

Substituting in the formula, we have

$$V^2 = \frac{4 \times 32.2}{3} \times \frac{86887}{51918} \times 0.6676$$

V = 6.926 ft second.

This result is less than the reality, for the much more important reason that V is only the *Horizontal component* of the molecular velocity, and it must be multiplied by the secant of the angle of emergence.

Molecular velocity = 6.926 × sec *e*. As the value of *e* is here 23° the real velocity is = 7.55 ft. per second.

S. H.

14. Continuing along the road we soon come to the junction of the Via Roma, which we have been following, with the Via Sassola. At the corner is a brick directing pillar, capped by a block of trachyte, on which the names of the two roads are carved. (See Figure 3, Plate I). The faces of the pillar are very nearly normal, the western and southern sides facing the roads, whilst the northern and eastern are supported about halfway by the attachment of two garden walls. It is on a level with this junction that the post has ruptured. The newly-formed arras to the upper fragment has split away to a slight extent at the S. W. corner, but the facet thus formed is much more developed on the western side; beneath, and corresponding to this on the lower part a piece, seven bricks in thickness, had been split off which also faced more to the W. The upper mass had shifted by rotation between 2 and 3 centimeters towards the W. at the S. W. corner. It seems therefore that the azimuth given by this object must be very near W. S. W.

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(1) The wall runs nearly N. and S. at this point.

15. Turning to the right, and descending the Via Sassola, we observe on our right some houses which are much fissured and their front or W. walls require propping , a fact which is quite significant of the direction taken by the shock. On the opposite side the houses are quite new , and have suffered less.

At the corner is the Caffè Centrale, where I was shown a clock which was stopped by the shock, but the owner did not remember the exact time. When placed by request, in the position it occupied at, the time of its stopping, it faced W. N. W. and would therefore confirm the last observation,

16. We proceed next to the Hotel Piccola Sentinella. This was little injured , a slight fissure running right along the arched colonnade , and a somewhat isolated building at its northern end being irregularly cracked. In the garden many flower pots had fallen, and a few showed the so called vorticose displacement, which a careful examination of their under surfaces explained. In the garden was a terrace surrounded by trellis-work supported from time to time by rubble work pilasters. All of them had been fractured at their base, but there was little displacement, and that of an irregular kind, due to the attachment of the trellis bars and other disturbing influences. Leading down to the lower garden from the terrace was a little staircase of a few steps, protected on the outer side by a low wall on which stood, loosely, a large terra-cotta flower vase containing an aloe plant. This vase (See Figure 4, Plate II) had fallen, having performed a quarter of a revolution, so that its upper surface with the aloe faced towards the wall which it had quitted. A careful observation of the mark left by its base and of its new position showed that it had been projected in a direction 15°. S. of E.: and. from the absence of any marked disturbing influences, gives some most important data.

From our previous observations it must have fallen during the second semiphase of the wave, which is confirmed by its position, from rotation in falling. At this point the angle of emergence was considerable, therefore its support must in the first semiphase have moved upwards and forwards. The great inertia of the upper part of the vase was such that it had commenced to fall back or rotate on its arras, when at this point the supporting wall in the second semiphase descended and returned, leaving it to continue its impressed rotation during its fall to the ground, which was sufficient to carry it through a quarter of a revolution, or 70.° or there about.

This is a case of « projectile » and comes under the head of my equation (Mallet. ibid. Vol. I. p. 158).

$$V^2 = \frac{a^2\ g\ \mathrm{Sec}^2\ e}{2(b \pm a \tan e)}$$

The *plus* sign being used when the projection is due to the direct shock, and the *minus* sign, when due to the return shock

a (horizontal ordinate) = 1.12 m. = 3.67 ft
b (vertical ordinate) = 3.47 m. = 11.38 ft

Assuming the angle of emergence to be the same as in the neighbouring observation in the Strada Castanito which was found to be, $e = 23°20'$.

We now have

$$\text{(Direct Shock) } V_1^2 = \frac{32.2 \times (3.67)^2 \times (1.089)^2}{2 \times 12.96}$$

$$\text{(Return Shock) } V^2{}_2 = \frac{32.2 \times 3.67)^2 \times (1.089)^2}{2 \times 9.80}$$

$V_1 = 4.27$ ft second
$V_2 = 4.91$ » »

This last value is the true value, for the pot fell by return shock.

S. H.

The direction of the wave path as deduced was not confirmed by another pot a few feet distant, which fell with the first semiphase, left an impression on the ground, and rolled to some distance; this, although giving the azimuth, was hardly safe to depend on for molecular velocity or angle of emergence, since it was not possible to know the exact position the pot occupied when it first touched the ground. It travelled along a line 10.° S, of W. So that the resultant of the two observations gives 2.° 30' S. of E. as the true wave path direction. Such a large error in two adjacent objects is probably due to the effect of the walls and pillar upon which they respectively stood, so that the latter probably gives the truest azimuth, as the pillar was more free to move in the true wave path. As we follow the road from the Piccola Sentinella towards the church of S$^{t.}$ Antonio we find that the houses had suffered much; but the directions of fissures were most irregular.

17. Before we arrive at the church of the Annunciata we reach a house, a corner of which had fallen to the N. N. E., from a fissure crossing W. N. W. to E. S. E., the shearing being at an angle of 60° so that the emergence would be at 30.° Opposite the Annunciata a wall convex to the N. had fallen, or been projected, in that direction.

18. On a bit of raised ground, on the right of the point where the rivulet crosses the road , was an old , round , rubble-work tower , with somewhat irregular thick walls. It may possibly have been an old windmill. The northern side of it had been sheared in a fairly regular manner by a fissure that commenced at the middle of the top of the tower and sloped downward and to 5°. E of N., giving an angle of emergence of 45°.

S$^{t.}$ Anna at Lacco is marked by many, but irregular, fissures.

19. Here fissures cross the house W. S. W and E. N. E., nearly parallel to its face. In the parish church was a crucifix which had fallen to the E. Candlesticks had fallen to the N. The irregularity of the socket of the first, and the tripod stand of the latter, render their evidence of little value.

At Casamonte a few houses fell, besides some walls, but without any discernible order.

20. At the chapel and house of the villa Panella all the fissures run N. N. E. and S. S W.

21. At Mezzavia some houses were cracked, in one of which was an old, coffin-cased clock, facing 5.° N. of W. which was stopped by both shocks.

At Cava di Mezzavia some fissures were visible which seemed to run mostly near N. and S. with a fall, in one case, to the E. One house entirely fell. Another clock close by, facing the N. E., was stopped by the first shock. At another part of the hamlet, fissures had mostly a N. E. and S. W. trend, but one had a N. and S. direction. The most certain indication, however, of the path of the earthwave was given by a chimney which had fallen to W. N. W., probably in the second semiphase, and also by a column which had fallen close by to the E. S. E. It will be seen that these two objects indicate pretty accurately the true path, and that these indications are confirmed by the result of the other rough ones of this district.

22. Near where the road « via al Lacco » unites with that from the Annunciata at a point near Menella, fissures cross the house in a marked manner from N. W. to S. E. and are widest towards the S. W.

Returning to the port of Casamicciola, we find close to it an odd shaped mass, the Villa Manzi, backed by a cliff, with an octagonal tower. This was very irregularly fissured, and seemed to suggest a wave-path somewhere about S. or. S. W.

The station of the Carabinieri, in the Strada Eddomada (that is, the road that leads from the via Margherita up to the entrance to the Piccola Sentinella and post office) was very severely fissured; but owing to the effect of windows, doors etc., the injuries were so irregular, that no certain indication of a wave path could be obtained.

23. Higher up was the Municipio, at the back of which was an old arcaded staircase, the arches of which, near the top of the building, had been filled in by masonry, except in the case of some small rectangular window spaces (See (*aa*) and (*bb*) Fig. 5, Plate I). The masonry on one side had been completely drawn out and had fallen (*bb*); on the opposite side the same had occurred: but the masonry was still standing (*aa*). On the second floor, the wall to the platform of the staircase, which formed the top of one arch and bottom of another, was fractured near its junction with the walls on each side, that is to say, near the spring of the upper arch (*a*). The part included between these two fissures was drawn out about two centimetres. The side of the building where this occurred faces S. W., and would therefore give a fairly certain azimuth coming from that direction.

24. On the apposite side of the road is the entrance to the Masseria della Torre, which is an L shaped building, with its longer axis from 5.° N of W. to 5.° S. of E. (See Fig. 6, Plate I). Its roof is crossed by two sets of

fissures. A triangular pyramid has been separated, but has not fallen, from the N. E. corner. It affords an angle of emergence of 10° 1.

The equation of the plane formed by the three fissures is

$$\frac{x}{3.64}+\frac{y}{8.62}+\frac{z}{12.20+u}=1,$$

where u is the prolongation of 12 20 below the surface of the ground where the other two lines meet: to determine this, we have two equations depending on a and b, which are

$$\frac{12.20+u}{u}=3.27$$

$$\text{and } \frac{12.20+u}{u}=3.64$$

the mean of these gives us

$$\frac{12.20+u}{u}=3.45$$

$$\text{or } u=5.00$$

from which we find our equation

$$\frac{x}{3.64}+\frac{y}{8.62}+\frac{z}{17.20}=1.$$

This determines, completely, the front of the earthquake wave.

The angle which this plane makes with the horizontal plane (x, y) is the complement of the angle of emergence, and is found (by the usual calculation) to be

$$\text{Cos } \Theta = 0'187$$

$$\Theta = 79° 13'$$

$$\text{Angle of emergence} = 10' 47'$$

The azimuth of the earthquake wave is the line perpendicular to the horizontal fissures; aud it divides the right angle (x o y) into two parts

$$u = 22° 53'$$

$$v = 67° 07'$$

S. H.

Now x bears 5° N. of W. to 5° S. of E: the azimuth of wave path is therefore from 17° 54', N. of E. to S. of. W.

Higher up the road was another house very much shattered; in which the fissures were very abundant and extensive. I am sorry from the complication I cannot understand my notes. The violence was such that the slab of marble forming the balcony was split, and the space between the fragments amounted to 2 1[2 centimetres.

25. As we ascend this road, some rubble-work columns of street lamps have fallen to the W. S. W., and, just before the road doubles on itself, a cottage has fallen in the same direction; a neighbouring lamp column, also, gives a similar azimuth.

26. In the strada Castanito, is a house about 20 meters N. E. of the shrine near the road to the Piccola Sentinella (See Fig. 7, Plate II). It consisted of a single room nearly cubic in form. The earthquake had separated the triangular pyramid at the N. N. E. corner, which had fallen. From the favourable absence of disturbing influences, the data for azimuth and angle of emergence should be of considerable value.

Equation of wave front

$$\frac{x}{4.37}+\frac{y}{3.31}+\frac{z}{6.12}=1$$

Angle of emergence = 23° 20'

UV = intersection of wave front and ground draw o. p. perpendicular to U. V.

It divides the right angle x o y into
parts u. = 37' 18'

v. = 52' 42'

The wall oy runs 18' W. of S. to 18 E. of N.

The wave path forms the angle u. with it of 37' 18', which would give the true azimuth 55° 18' W of S. or E. of N.

S. H.

Other houses close by give nearly similar results.

27. At the Villa di Majo in the strada Sassola the house was very violently shaken and fissured; many of the fractures seemed to denote a path E. S. E. to W. N. W. and angle of emergence of about 40°. This azimuth was confirmed by a new rubble-work column, plastered with mortar, and quite undisturbed by surrounding objects. It had been fractured at its base and split off part of the arras, but had not fallen. This building will be seen in Photo I. to terminate a row of houses, the W. and E. ends of which have suffered most. This is well indicated by the props to the Villa di Maio itself (Photo. I).

28. At the corner of the Via Sassola and the Spezieria, a small square house has its four corners directed to the points of the compass. Its S. W. wall was separated from the side ones by two vertical fissures at the coins, and had fallen out; the side walls were fractured at a high angle.

29. The house ending the group on the southern side of the Piazza had fallen to the W. N. W., and the whole mass of buildings was fissured at an angle of 47°, giving the value of 43° for emergence.

The Belvedere gives a S. E. and N. W. azimuth, but is overhanging a steep escarpment of loose tufa, which has no doubt modified the true wave

Fototip. F.lli Doyen Torino

Entrance to Menella. Looking nearly, due East, with the Parish Church of Casamicciola in the background.

path. Azimuth 27 passes (See Plate III) through it. We are now entering the area of maximum violence. The Parish church has been badly treated, and its clock stopped precisely at 1,5 p. m.: the face looks E. Nearly the whole of the S. side of the Strada Spezieria is down, and the débris is, on the average, two meters thick in the street. All the houses that cover the little hill to the S. of this district are destroyed.

The scene at this place 24 hours after the catastrophe was appalling. Women were sobbing and screaming, men howling, whilst soldiers were working frantically with the hope of rescuing the wounded, for the people had lost the use of their limbs from grief and would not help. The most pitiable sight was an example of human selfishness; a wine-seller much more concerned about his buried cellar than the lives of his neighbours and customers, and considering himself ill-treated because his barrels were not the first attended to. From this locality forward to the four cross roads the destruction was complete, to such an extent that one could not define the position of the street and houses.

When we arrive at the cross roads (Photo. III) and turn down the Strada Menella, we find the destruction has been great; but the houses, however, are good, and we are struck by the small amount of injury done to the walls, whilst the floors and roofs are all fallen in so that the buildings are gutted. From this we conclude that the angle of emergence is near 90°, and that therefore we must be near the seismic vertical. Lower down much damage had been done, and few houses were standing.

The locality known as Campo had suffered very severely. The space included by the latter, the parish church, and Menella, is that which has suffered most in the island.

The houses, many of them new, had been so completely ruined, that in most cases nothing but total rebuilding could have done anything towards rendering the locality again habitable, even supposing no more earthquakes were to be feared. The two small churches that were within this district, and which had arched roofs, completely collapsed and buried people in their ruins.

So far, we have examined all the effects on buildings to the E. and N., together with the meso-seismal area itself. To the S. we must content ourselves with only one observation, that of Frasso: for, although a few other farm-houses and *Cantine* are scattered about on the steep slope of Epomeo, they could not be examined internally, as they were deserted aad locked up. In addition, their position on a steep slope, and defective construction, would have rendered them of little use for study.

30. At Frasso the wave path, as was indicated by fractures, came from about 30° W. of N, and emerged at an angle of about 60°. The damage was severe, but capable of repair.

We now return to the cross roads at Menella and take the one leading to the district known as Fango, in the direction of Forio. Cugnone, just

below the road, gives no regular wave path, though there are many fissures. The road at this part has been almost completely swept away by avalanches of earth from the slope above, while the embankment on which it rests has been undermined by landslips.

31. A group of houses that lie to the S. of the letter G in the word Fango, on the map, gave a rough N. E. to S. W. path.

32. At the point where the byeway leaves the main road towards the last mentioned houses, stood a building that gave a path from 25° E of N., with an angle of emergence of about 60°.

33. Farther along, on the S. or upper side of the road, another house gave a rough N. N. E. to S. S. W. azimuth.

34. A few metres to the S. side of the road, at the same point, another structure gave a rough E. and W. azimuth. The resultant of these two problematical azimuths is 66° 15 E. of N.

35. There are some houses occupying the ravine due N. of the letter « a » in the word Fango on the map. One gave a path from E. N. E., another from N. E., or a resultant azimuth of 33°45' N. of E.

The bridge, crossed by the road and built of squared ashlar of Epomeo tufa, is quite uninjured.

36. As we descend the hill near Chiappa there is a porch, the place of which will be seen to form a segment of a circle (See Fig. 8, Plate I). The general strike of the structure is N. E. and S. W. The figure shews that there are fissures between side posts and road wall, two fractures in the curved walls, (*b*) others at the junction of these latter with the dressed stone door-posts. In addition, all the arch stones are disturbed and the key-stone (*a*) has dropped down, and from its vacant space a fissure extends up into the little superposed shrine. It is evident that the whole structure rocked very nearly in its principal plane; so that, where the adhesion was small, as between the dressed trachyte corner stones and door-post, fissures had formed. The two fractures in the side curved walls would seem to show a slightly more easterly azimuth. The keystone no doubt dropped whilst the two halves of the arch were shifting in each semiphase of the earthwave. The house itself gave an approximate N. E. and S. W. path.

37. A little distance to the N. W. of this point is a house which affords roughly an angle of emergence of 10° and a path from the N. E.

38. Retracing our footsteps, we take the road to S. Aniello, and, after passing the group of houses which are little injured, we follow the Strada Mezzavia. In the *masseria* of Signor Nicola Manieri some flower-pots fell to the E. S. E. The proprietor, in answer to a question whence came the shock, points with his arm in a direction which by compass proves to be from E. He says he felt severely the vertical movement and only slightly the lateral or undulatory, and that he has often felt stronger shocks. The angle of emergence appears to be very low.

39. Just beyond, a path leads off to the left of the road to some

houses which indicate roughly a wave path, running E. and W., perhaps a few degrees N. of E., the wall of the house being only slightly loosened.

40. Skirting the foot of Monte Marecocco we encounter the road from Lacco to Forio, which we will follow in the direction of the latter town. The road makes a bend on itself, and here, just at the foot of Monte Rognose, a house gives a path E. N. E. and W. S. W., probably a reflected one from the mass of Monte Marecocco.

41. Farther on, close to the junction with the lane to the right, a small niche-shaped shrine is built astride of a high wall. The strike of this top-heavy arched construction is 30° S. of E. to 30° N. of W. The arch is cracked in two places above, one of the fissures extending right down through the back or body of the shrine, whilst another traverses the plinth. The path of propagation must have been somewhere in the plane of the construction.

42. A house at the corner of the four cross roads gives a rough E. and W. path. These afford a resultant azimuth of 15° S. of E.

43. Calasisto gives an azimuth E. and W., but there are many fissures probably due to a reflected wave.

44. The *masseria* Spadara, the property of Signor Antonio Maltese, to whom I must express my thanks for his great courtesy and assistance, offers a most instructive example of the displacement of objects. Built upon the edge of a flat, batten roofed house, was one of those extraordinary complex chimneys of plastered rubble work, which are particularly characteristic of southern Italy. The sketch (Fig 9, Plate II) gives an idea of this style of construction. The main body of the chimney had rocked upon the roof, and the arras towards the E. had scaled away (*B*). The four pilasters, that supported a heavy, solid, conical top, had been broken off at their bases and the cone itself had slipped a distance of 8 centimeters in a direction of 35° N. of E. This was well seen on the base of the conical cap, which was black from smoke, except the white squares which were originally in contact with the little columnar support (*A*). We might at first sight feel inclined to take the line of shifting as the true azimuth of the wave path; but, for the following reasons, this was no doubt much more towards E. and W.

The body of the chimney, which is very heavy, rests half on the side wall and half on the rafter roof, the first being a rigid base, the second an elastic one. The plane of the wall runs N. N. W.

Now if a body, resting on such a compound foundation, were made to oscillate, and the oscillation formed a large angle with the junction-line of the solid and elastic bases, such oscillation would soon be resolved into others occurring at right angles with the said junction-line; and any loose part of the mass, (such as, in this case, the conical top of the chimney) would be made to shift its position in a direction parallel with the line of

rocking, and at right angles to one of the vertical surfaces of the solid base (in this case, the inside surface of the wall).

Only those who have walked across such roofs can form an idea of their elasticity. It seems that the wave reached the supporting wall, coming nearly from. E to W. and first tipped the chimney in that direction, causing the scaling that we see near the base, while the peculiar foundation upon which it rested soon caused it to rock in a direction at right angles to the junction line of supporting wall and the roof. Taking however a mean azimuth, deduced from the position of scaling and that of the sliding chimney-top, we have a wave path coming from 17° 30' N. of E.

45. Just west of Spadara, near the union of the three cross roads, the houses seem to show a N. to S. path, apparently that of a wave reflected from the trachyte mass of Marecocco and Zale.

46. A house near the church of St. Michele shows fissures similar to the last.

47. Another, opposite that edifice, gives an E. S. E. and W. N. W. azimuth.

48. St. Michele is one of the usual type of churches with a vaulted roof and small dome. It is fissured all along the centre of the arched roof, the axis of which runs 7° S. of E. to 7° N. of W. This would indicate a path somewhere near N. and S. in direction, which I take to be that of an earth wave reflected from the mass of trachyte above mentioned. In fact, most houses in this district seem to show a double set of fissures, one at right angles to an approximate E. and W., and the other to a N. and S. azimuth: the former being the effect of the direct shock, the latter, that of the one reflected in the manner above described. The iron cross on the Campanile has fallen towards the E. N. E: a result probably due to the combined effect of the direct and reflected waves. Besides this, a fissure crosses the body of the church at right angles to its axis and affords the most trustworthy azimuth obtainable, which would be from 7° S of E. This church was a specimen of a class of buildings most misleading in the indications of azimuth furnished by their fissures etc; and there were dozens of similar examples, in which, from complication, the destructive action seemed to have followed no definite direction, thus leaving the observer in the utmost perplexity.

49. Farther on, on the right of the road, a chimney has fallen to the W., probably in the second semiphase. The owner of the house asserts that the movement came from the direction of Casamicciola.

50. The masseria Sciavaca gives a path from the N. N. E, this also being, probably, that of a reflected wave, with an angle of emergence of 15°. At Monte Vergine the earthquake was felt, but no injury was done.

51. On the coast, midway between the Batteria della Chiaja and Monticchio, on the right of the road leading to the beach, a house that is quite normal has two fissures running due N. and S. separating its E. and

W. walls; they are quite uninfluenced by any wall openings, such as doors or windows, and probably give a very correct azimuth running E. and W.

In another house in close vicinity was suspended a cheap two shilling Dutch clock, whose pendulum oscillated in a plane 15° S. of E. to 15° N. of W., and which had not stopped. The wave, therefore, probably travelled nearly parallel to the plane of oscillation or nearly E. and W. thus confirming, roughly, other observations made in the same locality.

52. Returning to the main road from Casamicciola to Forio, a short distance E. of the church of St. Maria delle Grazie, we find a house which seems to give evidence of two distinct paths, one from the N. W. and another from the E.

The Palazzo della Stracea has a porch somewhat like that of Chiappa, but much deeper in its cancavity, with the side walls longer, so as to form a deep recess. The arched doorway lies at the bottom of this recess , and is much heavier. The whole rocked in an E. and W. direction, and produced a group of fissures in the side walls only.

53. The fissures in the church of St. Maria delle Grazie show nothing definite; but some objects on the altar had fallen towards E. N. E.

Some distance further towards Forio, a large building on the right gives an apparently distinct indication of a wave path from N. W.

A watch, also, had stopped at 1. 15 p. m.

54. At Torone, Signor Giovanni Angelomonte' s house gives a rough indication of a path from E. S. E. This may be a reflected wave from the mass of Epomeo. A French ormolu clock, whose pendulum vibrated 35° N. of W. to 35° S. of. E. had not stopped, but had been made to strike repeatedly.

55. As we enter the main part of Forio we see a wall opposite the church of St. Sebastiano, running E. and W., which had fallen to the N.

The town of Forio had suffered hardly at all. There were a few small cracks in the walls, and a few rotten walls had crumbled down; but nothing of any definite character was left to denote the features of the earthquake, although it was rather sharply felt.

We find, as we have seen, that the effects of the earthquake gradually diminish, as we recede eastwards from Casamenella; and we observe a similar diminution, in travelling towards the N. or W. of that locality.

Let us now proceed to the examination of the S. side of the island opposite to that where the earthquake manifested its maximum violence. We have first the great, massive range of Epomeo, which intervenes as a barrier between this region and the seismic vertical, and which must have to a great extent modified the effects of the shock as it traversed it. Again, the difficulties of study are still further increased by the fact, that the area occupied by the mass of the mountain is almost uninhabited, only a few canteens being found which, from their position, construction, etc., could not be depended upon for investigation. This area, therefore, formed a great

blank nearly in the middle of the affected region, adding much to the difficulties in the study of it.

Leaving Forio we pass through Monterone, where a few fissured houses are met with: but I could not obtain any azimuth. Some of the inhabitants felt both the shock of Friday and that of the following Wednesday; but some, only the latter. At La Piena the conditions and accounts were very similar.

At Panza the accounts were very variable, as the vibrations were very feeble. A few said they felt the shock of Wednesday.

At Ciglio the first shock was felt, but not that of Wednesday.

At Serrara Fontana the first shock was felt faintly, and one house was slightly fissured. The shock of Wednesday was described as two successive blows followed by a rumble.

Fontana, which must lie exactly in the centre of the great crater of Epomeo, suffered considerably and in a remarkable manner. The majority of the houses consist of a single room, nearly square in plan: in some, however, there is another, forming a second story, reached by a masonry staircase on the outside. The roofs are mostly vaulted internally and flat without, the corner spaces being filled in with loose fragments of tufa, and the whole being of great weight, but with little cohesion and elasticity. There were seven houses affected in the same manner. A number of fissures commence from the doors and windows, spreading upwards and inwards over the ceiling (Fig. 10, Plate I). In some cases all were united at their upper extremities by a coronal, or more or less circular fissure, which isolated the central portion of the ceiling. The side walls were little injured, showing that the lateral movement had been almost nil, whilst a vertical (or nearly vertical) series of waves had produced very evident damage to the roofs and ceilings. Every person declared the movement to be vertical, though one or two felt a feeble lateral or undulatory movement immediately following the first. All agreed about the first, thus fully confirming the physical evidence. No house actually fell.

At Moropano both shocks were felt, and one house was slightly fissured.

At Valle, near Barano, both shocks were felt, by some as vertical, and by others as undulatory.

In the town of Barano, most described the movement as undulatory, and one rather intelligent individual remarked the swaying backwards and forwards of water in a basin, thus proving the movement to have been as described. Unfortunately, the observer was not very clear about the direction of the water's motion.

I was told that at Vitoliere there were walls faintly cracked.

At Piejo shocks were felt, each being characterized by both vertical and undulatory movements.

From this point we pass to that first examined, having thus reviewed nearly the whole of the injured area.

CHAPTER VI.

Field observations of the earthquake of July 28th 1883

Going E. from the landing pier, the road is soon crossed by the Ombrasco rivulet. At this point is a square masonry shrine, surmounted by a wooden cross, which had been made to lean 15° N. of E. This angle, however, was not to be depended upon, as I could not discover the means by which the cross was fixed. The ordinary method consists in the use of mortar and wooden wedges.

Continuing along the main road, before we arrive at the Villa Maresca, we find an iron gate of the same type as that in front of the said Villa, described in 1881 (see Fig. 1, Plate I) and to be again referred to shortly. The wall, in which the former forms an opening, strikes 30° N. of E. The dislocations and fractures are very similar to those in its fellow above-mentioned, and would give an azimuth approximately parallel to its plane.

On the opposite side of the road, facing this, was a semicircular brick arch which had rocked in its own plane, as shown by two fractures about midway on each side, between the spring and the keystone.

The mass included between the two fractures was displaced downwards, having wedged its way, under the influence of gravity, between the shifting side-portions.

The Villa Maresca , whose face wall strikes 37° S. of W. to 37° N. of E., is fractured at right angles to this in a well marked manner. The angle of emergence seems to be so low, that it could not affect the fissures.

The garden gate (See Fig. 1, Plate I) had been thoroughlby repaired, and I had photographed it in its complete state 10 days before the shock.

This earthquake of 1883 has produced fractures and displacement exactly similar to, but on a grander scale than, those caused in 1881. The

description given of the former serves equally well for the latter, of course taking into consideration the proportionally greater violence in the latter case.

The ladder rails described in 1881 had not been repaired, and this shock has only aggravated the previous lesions.

It will be seen that the azimuth given by this locality in 1883 is indistinguishable from that obtained there in 1881; except that the two new observations afford another limit and a range between 37.° and 30.° N. of E., or an average of 33.° 30' N. of E.

2. The Villa Vedova Manzi, marked Cittadino on the map, is a very old house with rotten walls and timber. It suffered considerably in 1881. On this occasion it is totally destroyed. It is L shaped in plan, with the arms running nearly N. to S. and E. to W.; both the corners are shot off, a fact which indicates a wave path from 20.° N. of E., with a doubtful angle of emergence of 20.°, but probably lower.

3. The church of S. Pasquale is fractured across its principal axis, which lies 15° N. of E. to 15° S. of W.; objects fell off the altar forward, or towards 15.° S. of W.

4. The Villa Balsamo—as we proceed from the road up the drive that runs about 10.° or 15.° W. of N. the side walls, pilasters, and flower vases have been ruptured and thrown down at right angles to its axis, so that the road is lined on both sides with ruins. The twin villas strike nearly E. and W.: the northern one has its N. E. angle thrown out and fallen, and, were it not for the obvious irregularities due to the division walls, would give a nearly S. W. azimuth (See Photo. IV).

The fractures in the opposite building denote a nearly E. and W. wave path. Some rectangular seats of brickwork, capped by a stone slab and built upon the tile terrace, or court, have slipped towards a little S. of W. Altogether, I am inclined to suggest an azimuth of about 10.° S. of W.

5. A house opposite the entrance gives a wave path from 5.° S. of W.

6. At the branching off of the Rotaro road, a house indicates a doubtful wave path from 30.° W. of N.; due, in all probability, to some abnormality of construction, position, reflection, or to some other cause which I was unable to detect. The Monte della Misericordia is a remarkably irregular polygonal building and overhangs a steep escarpment. It has been reduced to a heap of complete ruins (See Photo).

A house opposite the Monte della Misericordia gave an approximate wave path from N. W. which is similar to the last observation but one, and is probably dependent on the same causes.

7. The church of the Madonna dell' Assunta is an interesting specimen of earthquake destruction. It is composed of a nave and side aisles. Its main axis strikes 5.° S. of W. to 5.° N. of E. (See Photo. VI).

Its E. end, including the facade of the nave and two aisles, has separated and fallen out, carrying with it part of the roof. The remainder of the building is fractured at right angles to its axis. The W. end and apse are very much

PHOTOGRAPH IV.

H. J. J. L. Dis. Fototip. F^lli Doyen Torino.

The two portions of the Villa Balsamo. Looking N. W.

H J J L. Dis

Fototip. F.lli Doyen. Torino.

Ruins of the Monte della Misericordia. Looking nearly due W.

Fototip F^lli Doyen Torino

Church of the Madonna dell'Assunta, Piazza dei Bagni, Casamicciola.
Looking nearly due W.

PHOTOGRAPH VII

H.J.J.L. Phot. Fototip. F.lli Doyen. Torino.

Chimney of the Stabilimento Belliazzi, Casamicciola.
Looking nearly N.

PHOTOGRAPH VIII

H.J.J.L. Phot. Fototip. F.lli Doyen. Torino.

Blank gateway in the Via Roma, Casamicciola.

fractured, but were supported by other buildings in contact with them. The angle of emergence is 28.°

8. The Stabilimento Beliazzi has a brick chimney of the factory type, with a stone cap consisting of a single well-trimmed block of trachyte (See Photo. VII).

The chimney is fractured in various places in its length, but the upper two metres have rocked in a path of about 5.° S. of W. resulting in the partial disintegration of the bricks and mortar, which have shifted one upon another without falling.

The district of Tresta, that lies along the S. S. W. bank of a branch of the vallone Ombrasco overhanging a steep escarpment, has been totally destroyed, so that no azimuth could be obtained.

Returning to the Piazza dei Bagni, every house surrounding it had fallen into a heap of ruin, or was liable to do so; so also the houses lining the road leading up to the Villa Barbieri.

9. Ascending the new zigzag road, the Via Roma, to meet the Via Sassola, we arrive at the blank gateway (See Photo. VIII.) — which should be compared with Photo. II. Nothing had been done since 1881 to disturb the column which is still standing. On the occasion of this earthquake it was projected nearly due E. and was accompanied by the greater part of the wall. In addition, the road that overhangs it (but at a lower level) has a fissure running parallel to it. The photographs when compared will give a remarkably good idea of the *great difference in the violence of the two great earthquakes*.

The main road that leads upwards from the Villa Barbieri to the entrance of the Piccola Sentinella has all the houses that line its N. side completely ruined. The shrine at this point, built of good brickwork, was almost undisturbed in 1881, but was reduced to a heap of fragments by the second earthquake.

10. The Piccola Sentinella will be but too well remembered as the tomb of so many victims, and was therefore naturally of considerable interest to me, especially as it was my usual place of residence when in the island. The building as a whole has remarkably few lesions, and had the earthquake occurred at any other hour, few victims would have lost their lives amid the ruins. In 1881 damage to the value of about 1000 francs was done to the building, chiefly detachment of the plaster and other superficial injuries, so that I slept there with comfort whilst making my observations immediately after. I had, however, taken the precaution to choose my bed-room in the centre of the building, which is composed of a long narrow range of apartments, with two short wings projecting at right angles to each end (See Photo. IX.) The axis of the building runs nearly S. W. to N. E. An acute angle, that terminates the S. W. side of the wing at that end of the building, was drawn out and fell on the occasion of the second earthquake; the N. E. side of the wing, which was the old dining-room, and some bed-rooms were also

ruined. The whole of the N. E. end, including the termination of the main building and the side of the wing, had been projected parallel to the main axis; the shearing, together with other fractures in the building, gave an approximate angle of emergence of 38.° It was this last part that converted the pretty garden into a heap of ruins. The social rendezvous of happy visitors, where merry laughter rang out to the musical tinkle of the coffee cups, is now the tomb of many of its occupants, for they are buried where they died. Only ten days before this tragedy, I was staying, at the hotel, to verify some measurements for my unfinished memoir of the 1881 earthquake. Although I was fully aware of the danger, it seemed impossible to conceive that in such a short time, I should return to the same spot and recognise only the battered and putrefying corpses of my former merry companions; for in fact one who sat next to me at table and frequently indulged in goodhumoured banter at my expense, on the subject of my seismic researches, had found his last resting place among the ruins of that terrible diningroom.

The azimuth afforded by the building was rather obscure, but seemed to be somewhere from between S. W. and W.

It may be remarked that, when by necessity we must inhabit a house in an unstable district, the safest places are the rooms in the centre of a building whose longer axis is parallel to the principal wave path, and especially is this the case in a low structure of not more than two stories.

In the present instance, had the inhabitants all been in bed and not collected in the drawingroom at the N. E. end, few would have been killed.

11. The Hotel Pisana gives a doubtful wave path from 26° S. of W. The building, though still standing, is terribly shattered.

12. The Villa Verde, opposite the entrance to the Piccola Sentinella, had been treated with great violence; it afforded an azimuth from about 20 W. of S. and a doubtful angle of emergence of 15°.

13. As we ascend from this point towards the Villa Sauvè, the road is flanked on the S. side by a high revetment wall. This wall is built a little higher than the garden (see Figure 11, Plate II.) and forms a kind of balustrade, strengthened every few metres by buttresses or pilasters, which at their upper end form a platform for a flower vase. The section and plan will explain the arrangement more clearly.

In all, six flower pots had fallen to the road below, giving excellent data for azimuth of wave path and molecular velocity. In the plan, the line of projection of three of these is shown, the others having been slightly disturbed: but all gave azimuths ranging between 10° and 13° W. of S., the resultant of all being 12° W. of S. The Villa Verde, it will be remembered, gave an angle of emergence of 15°?; but we are approaching rapidly the mesoseismal area at this point, and comparing its relative position with other observations in the neighbourhood, I am inclined to give an emergence at this point of 40°.

H.J.J.L. Dis

Fototip. F^lli Doyen. Torino

The Hotel Piccola Sentinella, Casamicciola. Looking nearly N. W.

The three flower pots thrown off gave three sets of coordinates to determine the path of the projectile; but they cannot be depended on in detail: I therefore make use of their mean value, in order to find a relation between the angle of emergence and the energy (1) of the molecular velocity.

Taking the centre of gravity of the flower pot for origin of coordinates, the equation of the parabola is

$$y = x \tan x \tan e - \frac{x^2 \sec^2 e}{4\,H}$$

The mean values of x and y were

$$x = +1.547 \text{ m.}$$
$$y = -5.853 \text{ m.}$$

Substituting these values in the equation, we find, after some reductions

$$4\,H = \frac{2.393 \sec^2 e}{5.853 \pm 1.547 \tan e}$$

I calculate the following table from this formula reducing the measures to English feet.

e	H (*direct*)	H (*return*)
± 30°	0.387 ft	0.526 ft
± 40°	0.466 »	0.733 »
± 50°	0.623 »	1.186 »
± 60°	1.124 »	2.479 »
± 70°	1.662 »	10.550 »

It will be noted that the energy measured by the return shock is always greater than that indicated by the direct shock, that it increases much faster as the angle of emergence increases: in point of fact, if the angle of emergence were 75° 56' the energy would be compelled to be infinite.

Assuming the angle of emergence to be 45°.

We have

$$4\,H = \frac{2.393 \sec^2 e}{5.853 \pm 1.547 \tan e}$$

If $e = 45$.

Calculating and reducing to feet, we have

H=0.4854 ft (direct shock)

H=0.8337 ft (return shock)

The mean value of H for the Earthquake shock of 1881, is

H=0.6030

S. H.

(1) I use the term energy to denote the height due to the velocity or $V^2=2gh$ of the molecular velocity. The energy of an earthquake, is simply the height to which a body would be projected, if the earthquake shock were vertical at that point.

The mean energy of the Ischian earthquake in 1881 was 0, 6030 and in 1883, 0,6595. The mean energy of the Calabrian earthquake was 2.544 f. or about *four times* as great.

S. H.

14. Retracing our steps we follow the Via Sassola to the junction of the Via Roma, and turning towards the centre of the town, we first meet our old acquintance the Villa di Majo. In 1881 this house was so much injured that it should have been pulled down; the fissures were many and wide, and one that involved the whole E. side of the building was open with an average width of 12 centimetres. Iron tie bars were inserted, the walls screwed together, the fissures filled with small rubble-work and plastered over, so that to external appearance all was neat and tidy. Such a bad opinion had I formed of this building, that only a few days before the last earthquake, having to pass by it, I did so running, for fear of a slight shock bringing it down upon me. My fears as to its stability were more than verified, for, notwithstanding an abundance of iron tie-bars and chains, the villa was completely wrecked, burying many people beneath its ruins (Photo. X. and XIX). The walls gave only an approximate azimuth from about W. S. W. and an angle of emergence of 48°.

14'. A group of houses just beyond give a series of cross fractures, denoting a wave path from S. W. and a good angle of emergence of 43°.

As we approach what was once the group of houses forming the district of the Spezziaria, nothing but a complete mass of ruins meets our view; the district is a heap of debris in which the walls are reduced almost to their original elements.

15. Further along, just before arriving at the Piazza di Maio, a house still standing on the N. side of the road gives a wave path 15° S. of W. and an angle of emergence of 60°.

The little hill that was covered by houses, just N. of the Piazza, is a vast heap of debris of masonry. (Photos XI and XIX).

Most of the houses lining the Piazza have fallen, or are ready to do so. The parish church is razed to the ground. From this point forward, throughout the district of the Purgatorio, we see nothing but utter ruin.

No better idea of the absolute destruction of buildings could be conceived than what was actually realized at Casamenella and Campo. Looking, on the following Monday, over the field of destruction, I could discern (with few exceptions) the wall stumps only remaining. In no locality in the island, (even where as at Tresta, the earthquake was aided by other natural agencies), was there such evidence of direct and intense violence (Photos. XII. and XIX). Naturally such an area could afford no data as to emergence and azimuth. As may be expected, here death was the rule: although I saw some of the injured inhabitants extricated alive, where they had been protected by a beam, or portion of a wall which had remained standing.

Following the road to Fango, destruction is written everywhere; landslips have in many places completely carried away the road, or covered it. The walls on both sides have fallen, so that for long distances the road was not even partly visible, and it required an attentive and nimble foot to traverse this encumbered path.

PHOTOGRAPH X

Fototip. F.lli Doyen. Torino.

Villa di Majo; looking nearly due E.

Fototip. F.lli Doyen Torino

Piazza di Majo and district just N. of it; looking about W. S. W.

Fotoip. F^lli Doyen. Torino

Casamenella; looking S. E.

Fototip. F.lli Doyen Torino

The Church of S^{t} Rosario at Lacco; looking nearly due N.

H.J.J.L.Phot. Fototip F^lli Doyen Torino

Main street of Upper and E. Lacco; looking from near S^t Rosario Eastwards.

16. At a short distance before we arrive at the branch road to Panella is a group of houses and a chapel. The indicated wave path is from 20° S. of E. and a house seemed to give an angle of emergence of 15°, but the chapel affords the value of emergence of 34°. From other indications in the vicinity, we are justified in accepting the latter figure.

The single-arched bridge, of good squared tufa ashlar work, was completely destroyed and reduced to small fragments. It was not visibly injured in 1881, and thus forms a standard of comparison as regards the violence of the the two shocks.

17. Panella is ruined, although parts of the houses are still standing (Photo XX.) The azimuth of wave-path here was 57° S. of E, and the angle of emergence, 30.° Another building, close by, gave an azimuth from 25° S. of E: a resultant of both would be 43° 30' S. of E.

18. Casamonte gave me a doubtful azimuth from 15° S. of E., but my friend Prof. P. Franco, from an independent observation, obtained a nearly N. and S. wave-path at the house of Sig. Michel Angelo Pontanara. The resultant of these is 52° 30' S. of E.

19. The roof of the church of S^{t}. Rosario of Lacco (Photo. XIII). collapsed, and the front wall, or façade, and low *Campanile* fell forwards towards 10° E. of S. It is broken off at the level of some iron tie-bars with which the church had been pretty thickly threaded.

A house opposite, and a little to the W. of the church, gives a doubtful angle of emergenee of 32°.

19'. Just E. of and below Casamonte a house indicates a very dubious wave-path, and an angle of emergence of about 37°.

The church of Annunciata has its principal axis directed 10° N. of W. to 10° S. of E. The façade was detached, but did not fall. I could not obtain a view of the remainder of the exterior, or of the interior.

20. Baudaja, near the Annunciata, gives a dubious wave path from 23° W. of S. and an angle of emergence of 22°.

The E. end of Lacco had suffered very severely, and there was hardly a single roof that had not collapsed, indicating the subsultory nature of the shock at this point (Photo. XIV.)

21. Following the carriage road to the marina of Casamicciola; at its commencement the N. wall which supports an embankment has crumbled, whilst that on the opposite side of the way is peculiarly affected, as will be seen by the diagramatic section. (Figure 12, Plate I.). It is a badly built rubblework wall, with little cohesion, and the line of wave propagation was at one part nearly normal to it, resulting in its rocking at right angles to its plane. The consequence of this is that the wall has been fissured and bent over toward the epicentre; the result, apparently, of pressure or traction rather than of violent shaking. Fallen portions afford a rough azimuth from 30°. W. of S.

22. A house just N. of the last observation gives a similar wave-path

and an angle of emergence of 30°, the data being numerous and conflicting.

23. On the slope of the hill, under and just N. E. of the Grand Sentinella, a *masseria* gave a wave-path from. 55° S. of W.

24. Continuing along the road we soon arrive at the Villa Manzi. A large massive gate column of good masonry, plastered, has been ruptured, and projected 15°. E. of N., though there were apparent disturbing influences.

25. The large square brown house, that stands at the neck of the landing pier, gave a wave-path azimuth from 40° S. of W.

26. Siano, on the slope above the port, afforded a rough wave-path azimuth from about 30° S. of W.

27. The Grande Sentinella lies at the end of a spur or buttress of Monte Epomeo, Casamicciola lying at its junction with that mountain. Its longer axis is directed N. N. E. to S. S. W.; its N. end was projected at an angle of 60° degrees and, with other fissures, gave a moderately good angle of emergence of 30°. The indicated wave-path was from 20° W. of S.. apparentlv due to the wall overhanging the steep scarp, and also to the existence of a series of window and door openings on one side. (Photos. XV. and XIX).

An incident somewhat remarkable in its character, in which the author played a prominent part, is connected with this edifice; and as it is in direct relation with the subject, perhaps he may be pardoned mentioning it here.

In the early part of the summer of 1883 one of my friends, a well known member of the English colony in Naples, called on me and asked an opinion as to the safety of Casamicciola from earthquakes, as it was his intention to pass the hot season with his family in that locality. In my reply I pointed out the peculiar character of the shock of 1881 and its predecessors, the resemblance to others on the flanks of volcanoes, the fact that this type has a tendency to recur, and at no great, and generally decreasing, intervals in the same locality; all facts that would lead me to expect a repetition of the disturbance at no very distant date. It was pointed out that there were no possible means of indicating any date for such a repetition, though, so far as my own individual opinion went, I did not expect to wait long. Further, from my observations on the former earthquake, I directed attention to the fact that, should another one take place from the old focus, the N. N. E corner of the building of the Grand Sentinella would suffer, and should therefore be avoided as a residence. My advice was not followed. On visiting my friend at the Grand Sentinella about 10 days before its destruction, I again pointed out the danger, and stated that the end of the house would be probably sheared off at an angle somewhere near 70°. Such statements were received with that amount of incredulity which they undoubtedly seemed to deserve. On visiting the ill fated building after the earthquake, my astonishment was great when I saw the damage almost exactly correspond with my predictions; the angle of shearing was 60°, or

Fototip F.lli Doyen Torino

Northern end of the Grand Sentinella; looking about S. E.

only 10° in error, whilst the sheared portion was in a direction 15° more N. than I had calculated, not having taken into consideration the window and door openings in one of the walls. The most regrettable part of all was that my poor friend lost his son, who was buried in that part of the building indicated as most dangerous.

I have called attention to this circumstance, not with any object of claiming to be a prophet, for under the lamentable circumstances I should have preferred being silent; but to demonstrate that, however defective be our means and processes of observation, we should avail ourselves of them in planning and reconstructing buildings in an earthshaken district.

A few yards to the S. of the last mentioned building is a small house occupied by a man and his wife. The house consists of two rooms, one superimposed on the other. The upper one communicates with the lower part by an outer staircase of masonry (in Italian country fashion) which leads down to a yard. The two inhabitants were asleep in a bed, which was situated in the corner of the upper room opposite the exit by the doorway to the staircase, when they were suddenly awakened by the shock. The husband jumped out of bed, tumbled sprawling over a chair, regained his feet, crossed the room, unbolted the door, descended some twenty steps, and when he arrived in the yard the earth movements were still perceptible. I had the same series of actions performed before me, and 31 seconds were required. When we reflect that these were originally executed under the difficulties of darkness, fear, and unstable ground, and reckoning also the amount of time necessary for a person to pass from sleep to a state of consciousness, and to realize the real condition of affairs, I think we must admit that the general estimate of 15 seconds as the duration of the shock is far too low: nevertheless, others valued its duration at as low as seven seconds.

I would here remark that an inquiry into the time that elap ses between the first sign of an earthquake and its last sensible vibrations, although a subject of much popular interest, is, for various reasons, of little value to the seismologist. A person lying in a soft wool or feather bed, resting on springs, would not perceive much movement if near the seismic vertical, and would be sensible of it at all, only at its maximum development, whereas the house over him might be seriously injured. Another individual sitting, standing, or lying on the ground, or lower chambers of a house, would receive the shock directly, and would perceive, not only any precursory tremors, but also the last undulations. Were the estimates of these two observers compared, a great disparity would appear in the time during which each perceived the disturbances. Again, there might be two stations equally distant from the seismic vertical, having the same kind of rock transmitting the impulse, yet one might be situated so as to receive one, two, three or more reflected waves, whilst the other might be simply

affected by the direct one. As a consequence, the duration of the earth's movements in the first case would be far greater than in the second.

28. A variety of circumstances, on three different occasions, prevented my seeing the Hotel Bellevue (Photo. XIX). My friend Prof. Franco, however, gave me a sketch-plan of the injuries, which seem to indicate a wave path from 10° W. of S.

The houses that line the marina of Lacco Ameno have suffered in an interesting manner. Those on the side of the road towards the sea have suffered less than those opposite, where the ground begins to rise and is of tufaceous nature. Those on the sea side, whose foundations are buried on the loose sand, and whose walls, during rough weather, are reached by the surf, are practically uninjured.

We here have a striking example of the effects of geological structure in modifying earthquake violence; for here we see how, the looser the particles of a rock are on which buildings rested, the less they have suffered.

29. Turning up the road towards Mezzavia, we encounter the large Villa Manzo, the property of Mr. L. Nesbitt, whose name will be ever memorable for his courage, self sacrifice, and true charity during the anxious excavation of the wounded. Although he was one of the greatest losers in the island, and had a narrow escape of his own life, it was by his direction and example that the stupefied survivors were roused to the work of rescuing, whilst he stripped his house of furniture for the use of the homeless inhabitants. I must here express my gratitude for that gentleman's kindness and hospitality, which the disastrous circumstances rendered invaluable.

This Villa Manzo is a somewhat complex structure, though nearly symmetrical in its arrangement. It has been added to at various times, and some late additions are of a most massive kind. The longer axis of the Villa is directed 10° E. of N. to 10° W of S. It exhibits fissures produced by the earthquakes of 1828 and 1881, whilst of that of 1883 there seem to be two sets. The first or direct shock was denoted by a series of fractures running parallel to the longer axis, that is, in an azimuth from 10° S. of E. Some walls of the front or W. face were projected in that direction. On the table in the kitchen there stood, at the moment of the earthquake, a plate filled with raw egg ready for making an omelet. The earthquake caused a swaying movement in the liquid egg; so much so, that it was spilled over the S. E. and N. W. edge of the plate and dried on the table-cloth. M.r Nesbitt had observed this with much intelligence and deduced the wave-path azimuth from his observation; and he replaced the table-cloth and plate for us to see the exact condition of things, at the moment of the occurrence.

In the same room was a cupboard in which stood one of those tall brass lamps for burning oil, of a modified Pompeian style, in which the centre of gravity is rather high. This fell forward on to the floor in an azimuth of about S. E. to N. W. On a shelf was a crucifix with a heavy

wood block for a base. This had been twisted round to face N. W., but afforded no safe data for wave-path azimuth. Combining the first three observations, we have a resultant azimuth running between 33° 30' S. of E. to 33° 30' N. of W. The second group of fissures formed a large angle with the former, and indicated movements in an azimuth from about N. N. W. and S. S. E., which are probably the result of reflection from the neighbouring trachyte.

St. Restituta exhibited some very anomalous fractures that were not safe to depend upon. The apex of a small plastered masonry obelisk fell (I was shown the spot but could not verify it) about 20°. S. of E.

30. The Casa di Arbusto is a large rambling country « Palazzo », and from the almost certain presence of one, if not two or more reflected waves, as also from the structure occupying a declivity, it will be evident that the conditions were not very favourable for investigation.

Two brick chimneys, built around an opening on a flat battened roof. had slipped in a line nearly E. and W. so that the tube of the chimney was no longer continuous with the corresponding opening in the roof. A pilaster, similar to many others in the same garden, fell to the N. W. The two observations afford a resultant of 15° S. of E., which however we should accept with great caution, owing to the unfavourable circumstances already mentioned.

31. The hamlet of Mezzavia is all in ruins; one house above it gives an azimuth from 30° S. of E.

32. The church of S^{nt}. Aniello gives a doubtful wave-path from 15°. N. of E. and angle of emergence of 15°.

33. At the Villa Calasisto, two gate column caps of dressed trachyte were projected about 45° N. of W. A dressed trachyte pilaster, forming a balcony corner to the house, was projected in a line 5° S. of W. The resultant of these two is 25 S. of E.

34. At Monte Vico, just N. W. of Lacco, the house of Giovanni Calanno has its S. E. angle fallen. The cemetery wall on the E. side has also fallen. For both these observations I am indebted to Prof. P. Franco.

The Torre di Zale, or Castello della Duchessa Acquaviva, has only slightly suffered. It has enormously thick walls built buttress-wise and is only two stories high. The old Casa Colonica is slightly cracked, as is also a new building close by.

At the four cross roads, before arriving at St. Michele, the houses give a rough set of azimuths between N. and 20° E. of N.

35. The church of St. Michele, as in 1881, showed two distinct groups of fractures. The main axis, it will be remembered, runs 7° S. of E. to 7° N. of. W; it is fissured at right angles and parallel to this axis, the greatest injuries being in the former direction, which would give a direct wave-path from about 7° S. of E. and a reflected one from 7° E. of N.

36. The church of St. Sebastiano at Forio is a large and massive

structure in classic style which has never been finished. At its S. W. angle was a slim campanile, square in section, in which was an unfinished spiral staircase built round the interior of the walls. The structure was of combined ashlar and rubble work, pointed with Roman tiles (Photo. XVI), in which also the arched openings for the bells were constructed. It will be seen how remarkably clean this tower has been sheared off, and almost unaffected by any irregularities of masonry or wall openings; the attachment of the staircase only seeming to have slightly modified the lower angle, carrying it a little to the S. side. The plane of shearing is inclined at an angle of 75° degrees, giving an angle of emergence of 15°, and it strikes 40° E. of S. to 40° W. of N. and would give an azimuth from 40° N. of E. This, however, I feel inclined to reduce to 30°, owing to the staircase attachment, and also because a house almost opposite gives a very good wave-path azimuth from 30° N. of E. which is an additional justification for the reduction.

37. To the N. W. of St. Sebastiano a remarkably distinct azimuth from 20° N. of E. is obtained.

The Church of St. Michele di Monterone has a low dome-shaped roof, oval in plan; this is fractured across its major and minor axis, but its complex form and the irregularity of its construction, combined with the peculiar arrangement of the lesions, rendered it incomprehensible to me. The iron cross on the roof inclines to the S. E, but I failed to discover the mode of its insertion.

38. Opposite the church of Monterone is a house, isolated on three sides, which served as a school. On the roof was one of those peculiar masonry chimneys (See Figure 13, Plate II) of the same type (though differing considerably in detail) as that, already described, of Spadara. The tiles covering lateral smoke apertures on the N. and E. sides have fallen, and the heavy cap has slipped along a line towards 5° S. of W. and gives a pretty accurate wave path 5° N. of E. The length of this displacement was 12 1|2 centimetres, which shows the great amplitude of the vibrations; unless the change of position was progressive and took place by a series of shifts, which is hardly probable.

39. Higher up the hill of Torone (1) the houses are very severely damaged, and one has a more simple chimney than that just described. A large flat plate of concrete, forming the cap, was supported on four little columns, and had slipped completely off, falling in a direction 7° S. of W. and thus confirming our last observation. At the summit of this district, the houses have been violently fractured and give an approximate E. and W. path.

From this point we descend to the road from Casamicciola to Forio.

The church of St. Maria delle Grazie is a heap of rubbish.

39'. Just W. of this point a group of houses gave apparently good

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(1) The part of Monterone that bears this name, and not the S. part of Forio.

PHOTOGRAPH XVI

Fototip. F.lli Doyen Torino

The Church of S. Sebastiano, Forio; looking nearly due East.

data for angle of emergence, which puzzled me much, (since this result was not in accordance with other observations in the neighbourhood) until I discovered the cause. Four different observations of fractures gave respectively 53°. 30'., 56°. 30'., 51°. 30'., and 59°, the mean of which would be 55°. 31' observed, or equal to an angle of emergence of 34°, 29'. The wave-path azimuth ranged within E. and S. E.; but as the house is built on the verge of a steep scarp normal to the wave path, and the oblique fractures depended on a certain amount of slipping of the foundations, we must exclude the whole of these data.

40. Lower down, close to the old castellated building or tower, on the roof of a one-story house, were a number of plaster pilasters; one was fractured and had rocked, resulting in the crumbling away of its arras on one side, so that, as the upper portion did not fall when it came to rest, it remained in a leaning position. The whole of the changes pointed to a wave path coming from 15° N. of E.: a supposition which was confirmed by another column close by, which had been treated in much the same way and with a similar result.

41. We turn to the right and pass the little chapel at the corner; and we are able to examine carefully a large house, almost next to it, within and without. Groups of fractures all went to indicate a good azimuth from 5° N. of E. and an approximate angle of emergence of about 20°.

The district of Monterone, or more properly the more southern part of it, has suffered very severely; there is hardly a house that has not fallen or was not at least in great danger of doing so, so that a careful examination was a very perilous undertaking. The mortality was very great here, in consequence of the severe injuries to the houses.

42. The church of S. Francesco of Forio is fissured in an irregular manner, whilst that of S. Maria di V. P., close by, gives a wave path from 10° N. of E. The Rev. Sac. Rafaele Rogine informed me that some fishermen 3 miles out to sea from the Punta del Imperatore felt as if a blow had been struck under their boat.

The church of San Gaetano is fissured in various directions so that I could make nothing definite of the injuries. St. Antonio likewise was fractured in a complex manner, and seemed to give two wave-paths, one directed 12° S. of E. to 12° N. of W., parallel to its main axis, and another at right angles to it. Some candlesticks seemed to have fallen towards 12° N. of W.

43. A house close by gave a very good azimuth from 25° N. of E.

44. The church of S. Maria di Loretto was very severely damaged. I give here a sketch plan from my note book, which will help the explanation. (Figure 14, Plate II). The campanile that occupied the N. W. corner over the aisle has fallen on the roof of the nave and crushed it in. The bell had fallen roughly 15° N. of E. of its original position, but it may have been disturbed in its fall: though I think it more likely that the whole mass

crushed through the flimsy and rotten roof at once. One large fracture traverses the whole N. end of the building in a line with the crushed in roof, the nave, the two aisles and the sacristy. Another slight fracture crosses the W. aisle about midway between its extremities. Two other fissures extend along the centre of the arched roof of both aisles at the N. end. In the sacristy, the two end walls are detached by fissures, and a fracture extends along the centre of the arched roof. Against the S. wall was a large picture, which fell forward on to the altar and was transfixed by a cross standing thereon. Whether we are to regard this arrangement of injuries as the result of one or two wave paths it is difficult to say. I cannot but think that there were two, but whence the second came does not seem evident. Even supposing it to be a reflected one, whence could it have been reflected? For it is hardly conceivable that the trachytic mass of Zale etc. could effect such remarkable damage at so great a distance. A remarkable fact, worth mentioning, is that it is chiefly in the churches of Forio that complex fracturing took place.

The Casa Millone, close by, gives roughly a double set of fissures, indicating approximately N. and S. and E. and W. paths.

The church of S. Carlo Borromeo is much fissured and has its cupola and dome fallen; but I could not make out the wave-path.

45. As we quit Monterone for the road to Panza, one of the last houses gives an azimuth from N. E. and an angle of emergence of about 12°.

46. The house of Capizzo has been severely damaged and gives a good azimuth from 40° N. of E.

47. Farther on, the church of S. Maria delle Grazie gives a doubtful wave-path from 30° N. of E.

48. At the locality marked by the above number, three flower pots had fallen in a line 30° E. of N. and a fissure in the house indicated a similar azimuth.

49. N. of this point a house was sheared at right angles to a wave path from 30° E. of N.

50. The villa Pezillo, marked Calitto on the map, afforded a most interesting and instructive example of earthquake injuries. Unfortunately, on two different occasions when I visited the house, the keys could not be obtained, and no internal examination could consequently be made. A chimney was pointed out to me as having fallen 5° E. of N., but as the fragments had been removed and had, before touching the ground, pitched on another wall, the observation was of no value. But the most important point in this locality is a side entrance from the branch lane that leads from the Panza road to Matera. This entrance (Photo. XVII) is through a double iron gate flanked on each side by cylindrical plastered ashlar pillars, which are capped by a heavy plate, upon which rest the pedestals for the flower vases. These vases were retained by pieces of hoop iron, passed up the centre of the stand some distance into the cup part and there buried in strong cement.

PHOTOGRAPH XVII

H.J.J.L.Phot. Fototip. F^lli Doyen. Torino.

Side entrance to the Villa Pezzillo; looking towards 30° W. of N.

H.J.J. L.Phot. Fototip. F^lli Doyen. Torino.

Gate of the Villa Gastaldi some distance N. of Villa Calitto (Pezzillo); looking nearly due W.

It will be seen in the photograph that the two pillars are supported on their outer sides by an ashlar-work wall which strikes 30° N. of E. to 30° S. of W. The capitals of the columns, as well as what they support, have slipped along a line 25° W. of S. Both flower-pots had been violently rocked, but, owing to the iron attachments, they could not fall; they give no data for azimuth.

At Torre Vecchia, the masonry was of such a villainous type that I could only make out an uncertain azimuth from 20 E. of N.

The Villa Gastaldi, that lies on the slope of Monte Corvo, is much damaged and ready to fall; but the gateway is most interesting. The pillars (Phóto. XVIII.) are cases of squared dressed trachyte with a core of tufa rubble work. The plane of the gate is directed 5° E. of S. to 5° W. of N.: the N. pillar is supported by a wall whilst the one to the S. is kept up by a buttress on its S. side and a low wall on its E. The two pillars are more or less rigidly connected together by the ironwork on which the word Gastaldi is written. It will be seen that they have been subjected to very complex movement and are severely dislocated and fractured. The caps have rotated in a direction from W. to S. to E. to N. or, in a direction (if viewed from above) the reverse of that of the hands of a clock. Here we have another example of so called vorticose displacement: but the effect is, possibly, the result of two shocks, one arriving a little later than the other, the second probably being reflected. The cause seems not to be a local one, due to irregular attachment, as both caps are treated in a similar manner.

If we return to Monterone by the mule path that winds along the W. flanks of Epomeo, we may observe that nearly all the houses have lost their angles or sides that face the S. W., showing that the principal wave-path was from the N. E.

51. At Panza, the Chiesa della Congrega affords evidence of a wave-path from 25° N. of E. and a low angle of emergence.

52. The parish church is cross-fractured at right angles to its axis, which is 15° N. of E., and a window filled in by masonry was pushed out from behind; a fracture along one of the aisles would however indicate a much more northerly path, and it would not be exceeding reasonable bounds to give an azimuth from 25° N. of E. as in the preceding observation.

It is only the oldest and most rotten walls of this village that have suffered destruction, and the damage was such that little could be learned as to direction of wave-paths etc.

53. Just before the commencement of the branch road to Matera, a house indicates an azimuth from 25° N. of E. and a doubtful angle of emergence of 34°.

53' Between Matera and Ciglio, many houses seem to give an angle of emergence of 34°, and a N. E. and S. W. wave-path azimuth,

54. Opposite S. Giacomo, at Ciglio, a house afforded an azimuth from 25° E. of N. and an angle of emergence of 34°. A few yards above, an

approximate azimuth was obtained from 30° E. of N. with a good angle of emergence of 40°. Above this, another building gave a wave path from 35° E. of N. and the same angle of emergence as the last, or perhaps a little less. These three observations in the same vicinity give a resultant azimuth of 30° E. of N.

At the top of Ciglio some flower pots were projected in an approximate S. W. direction, thus confirming the last observation.

55. The Syndic's house at Serrara Fontana is much fissured, but capable of repair, as are all the houses in this village, with one or two exceptions. I obtained from the fissures an azimuth from 30 E. of N. Six other houses afforded good azimuths from 15° E. of N. The Church gave a similar result, but the house of the parish priest indicated a wave path from due N. This counterbalances the too eastern azimuth of the Syndic's house, so that we have one of the most definite azimuths, either compound or otherwise, in any one locality. One house gave a most doubtful angle of emergence of 38°.

I started on this excursion round the island accompanied by my friend Prof. P. Franco, immediately on reading the following announcements in the « *Roma* » newspaper of August 12th and 13th respectively: « To night a « telegram was received from the Syndic of Serrara Fontana by the Minister « of Public Works.

« The telegram announces that at that place one observes large fissures « of the ground on the southern side of Epomeo.

« The old fumaroles have ceased to act. The thermal waters are exhausted. « From the new fissures of the earth dense vapours are issuing. The « rumblings succeed one another with great frequency »: and « It is said « that on the south-west flank of Epomeo a fracture has opened one kilometre « long and 30 metres deep, and attributed to a slight depression of the « ground ».

On our arrival at Serrara we presented our letters from the Prefect and requested permission to thoroughly examine the locality. The Syndic placed at our disposal the two *assessors* who were his informants. We were led along just below the ridge of Epomeo, by Bocca della Serra, the Vado di Frassitelli and the Falange, to Mt. Nuovo: a 3 1[2 hours' walk in a broiling Neapolitan sun in August, without breakfasting, a bad preparation for our coming disappointment. The first point in which we found we had been deceived was as to the locality of the promised natural wonders: they proved to be not in the commune of Serrara Fontana, but above Lacco-Ameno. Then again, the so called fissures or fractures turned out to be mere landslips that I had visited, examined, and photographed 36 hours after the catastrophe. The fissures were not a kilometre long, and were simply such as form along the edge of all landslips, not one being more than 30 centimetres broad. There was no appreciable vapour escaping at the time of our visit, nor for a week or two afterwards. There were people, however, who declared that they saw vapour on the morning after the catastrophe. If any one examines

the material composing these landslips he will remark that it is a much decomposed tufa, very variegated in colour, showing the effects of the fumarolic action to which it has been exposed. In fact this locality was part of the fumarolic area of Monte Bastia and Monte Cito. Nowwhen, as a result of landslip, a large mass of muddy tufa, which has been kept hot and moist by the percolation of thermal vapours through it, is disturbed and turned over, there will arise an amount of vapour proportional to the difference in temperature and humidity of the mass and of the surrounding atmosphere. Such an escape of vapour will naturally only last for some hours, as was noticed, indeed, in the present instance. In the hope of finding some evidence of volcanic action I have visited with care all similar supposed fissures ; but after some days of starvation diet, composed of abominable, bad bread, and rotten cheese, combined with continual climbing from daybreak to sundown, in an extraordinarily hot Neapolitan summer, I did not meet with the slightest success. Yet, to me, holding as I do the volcanic nature of this and the earlier earthquakes, the appearance of any such phenomena would have been in the highest degree acceptable.

56. We now arrive at Fontana, a locality perhaps of as much interest as could well be concentrated in such a small and miserable place. In general it afforded evidence of much the same in kind as in 1881, but far more remarkable in extent. It will be remembered that the houses here consist of one or two rooms, placed one above the other , with arched masonry ceilings and batten roofs. Fissures extended radially inwards towards the centre of the ceiling, where they were sometimes united by an annular one (Figure 10, Plate I.) The portion of the wall above the wooden trave was detached as a triangular or V shaped piece, with the bent or broken plank as its base. All this points to a vertical upthrust blow. Besides this type of damage, which had ruined many houses, was another set of fissures quite as universally distributed. They were completely independent, and denoted far less violence, and did not in any case appear to have been the actual cause of a house falling. They indicated a wave-path azimuth from between N. N. W. and due N, at a low angle of emergence.

57. The Franciscan convent of S. Nicola occupies the highest point of Epomeo and is cut out of the solid tufa. The façade and a portion of the nave of the church are built in masonry, but the principal part is hewn out of the solid rock. The centre piece of the main altar is a little portico-shaped shrine, in coloured marbles, the plane of which has an E. and W. strike: it shows by its dislocations that it was rocked in an azimuth approximately N. and S. In the aisle, a picture, propped in a position similar to that of the shrine, fell toward the N. The small altar in this part of the church runs E. and W. It is of inlaid coloured marbles. The projecting slab, or altar cap, projects beyond the main mass and is supported by two brackets , which consist of a long slim back plate and a top-heavy cap

or head in carved marble. They were held in their places by a little white cement, probably plaster-of-paris. One of these brackets had become detached and had fallen forward towards the S.: the head, where it came into contact with the slab of the altar step which was broken, left the mark of the point of contact. These indicated a true N. and S. path. We must remember that in whatever direction the movement came, such a mass must inevitably fall forward, as a consequence of its unstable equilibrium (even had the movement been nearly at right angles to it). Under such circumstances it would be highly injudicious to accept such data for an azimuth; but the other two observations combined with this one give fairly trustworthy evidence of a wave path in a N. and S. direction.

A short rubble pilaster that caps the highest point of Epomeo is the trigonometrical mark. It showed evidence of having been detached at its base, but indicated no definite direction. Some weeks after my return to Naples, an individual told me that on a visit to S^{t}. Nicola before the earthquake, he had stood on this pilaster and then tried to overturn it! Hence the observed disturbances; an instance of the deceptions against which seismologists in the field must be constantly on their guard.

All the flanks of Epomeo are strewn with loose blocks of hard tufa, that by atmospheric agencies have been detached from the higher parts, and with, probably, much assistance from earthquakes, have rolled down the more or less steeply inclined slopes. During the earthquake, one of considerable size, was detached near the Falanghe, and, in its descent, cut as clear a path through the chestnut trees as could have been cut by an axe. Looking from above down its path, its direction was indicated by a long and almost straight avenue. At the extreme W. end of the landslip above Fango a large block had rolled down through a vineyard and was perched at the very edge of a terrace, only a few paces from a farm house and in such a position that a few strokes of a pick, or a slight earthquake, would have made it play havoc with the threatened building. Another of these blocks that had reached its present position (some distance S. E. of S. Nicola), many centuries since, was deeply buried in the surface soil. Now when a mass of porous rock, such as tufa, becomes imbedded in a saline volcanic soil (the result of fumarolic action), such as that of Ischia, there ensues an important and very interesting process of disintegration. The upper surface of the block becomes covered with algae, lichens etc, and so rendered more or less impermeable. On the sides, however, a continual crumbling goes on, as the drying of the moisture by the sun and wind takes place. To replace this lost humidity more water ascends into the mass by capillary attraction carrying with it sulphates, nitrates carbonates etc. in solution, derived from exhalations and from the soil itself. As this solution dries on the surface the salts crystallize and split off a thin layer of rock. This disintegration (which goes on with considerable rapidity) erodes the lower parts of the block, so that the upper

parts overhang. It is this process (*) that has carved out that remarkable rock known as « Il Fungo » (the mushroom) which lies a short distance out to sea opposite Lacco, though, in that case, sea salts were the agents of erosion. But to return to the rock of which we were speaking. Here the disintegration had proceeded somewhat irregularly: and the rock being flat in horizontal section, the lines of erosion from each side had united, and a ring shaped mass had been the result.

The remaining arch, although very hard, had been fractured in three different places, so that the two resulting morsels had fallen on the lower part of the mass and then bounded off in a S. W. direction. This rebound, combined with the irregularity of the surface upon which the bodies came to rest, rendered it impossible to deduce any azimuth, although the case afforded an interesting illustration of the violence of the earthquake.

After a supper consisting of black bread and a salad of unripe tomatoes and onions, followed by a night of misery, we descended to Maropano.

58. Some distance before entering that town, above and to the right of the road, stands the villa of Signor Angelo Migliacio. A glass cupboard in the wall of a room faces 26° E. of S. The glass fell backwards and forwards in a line about 40° W. of N, and 40° E. of S. The S. corner had been nearly shot off by a wave coming from about 5° W. of N. These two observations give a resultant azimuth from 22° 30' W. of N. which was roughly confirmed by a house close by.

59. The Church of S. Giovanni Battista has its principal axis 40° N. of E. to 40° S. of W. It consists simply of a nave. A fissure commencing in the centre of the top of the doorway at the S. W. end, extends upwards all along the middle vaulted roof, then descends on the N. E. end wall, completely encircling an old blocked up window on its way.

The two walls at the N. angle are entirely separated, and the fissure is continued upwards to meet that along the vault at about an angle of 45°. About one third of the way from the entrance, along the N. W. wall, another fissure, commencing at its junction with the roof, extends downwards. Another fracture runs along the top of the wall towards the N. corner; while still another occurs in the vault between (and parallel to) the last and the great fissure along the centre of the vault. There is also a slight crack symmetrical with that portion which unites the N. corner fissure with the main one of the roof of the building; this, however, does not reach the corner, The great central fracture indicates an azimuth from 40° W. of N.; but the peculiar injuries in the N. corner and the N. W. wall led me to assign in the field 30° W. of N. as a fair estimate. This, however, after a calm and deliberate study of the church plan with all

(*) The rapid destruction of the lower parts of the tufa walls throughout the Naples volcanic district is due to the same cause.

these fractures, I am inclined to reduce to 25° or perhaps even 20° W. of N. The emergence seemed to be practically horizontal.

In a house near the church a lamp fell in a direction about 25° N. of. W., so far as one could conjecture its probable behaviour from its position when replaced by the owner, thus roughly confirming the last observations.

In another house in this village a nearly square room faces 30° N. of W. and its side walls are fractured , the fissures being two on each side ; the larger, however, pass through door and window openings, so that more than an approximate azimuth could not be deduced; this, however, was sufficient to confirm other observations made in the same district. Against the S. E. wall hangs a picture suspended by a short string. It was tilted out from the wall by its base, being made to rest on two nails in the usual fashion. The shock, being very nearly normal to its face, must have made it approach and recede from the wall, so that the weaker of the two base nails was extracted , and the picture made to incline to one side (Figure 15 , Plate II.). This effect is in accordance with what one would infer from the injuries done to the house in which it occurred.

At Barano, the church of S. Rocco has a peculiar fissure along its roof, with two branch fractures extending down its W. wall.

The peculiar arrangement of these injuries prevented my deducing any results from them.

60. The church of the Congrega Madonna delle Carmine affords an approximate azimuth from 45° W. of. N. and an apparent angle of emergence of 18°.

61. Opposite the Parish Church, the house of Signor Matteo di Miglio exhibits an instructive series of large fissures, indicating an azimuth from 30° N. of W. The houses in the upper part of Barano have been severely fissured so that even some of the better ones must be rebuilt , whereas the lower part of the village is very slightly injured.

Many of the houses in Testaccio are cracked, but in no case seriously.

62. At Piejo the church is slightly fissured and the steeple fractured, a result which; as looked at from below , appears to indicate a wave path from the S. W. The facade , however , has separated from the nave-body and would indicate an azimuth from N. W. My friend Prof. Franco made it 30° W. of N.: so that, taking the mean, we obtain 37° 30' W. of N.

63. A house opposite the church indicated an azimuth from between 25° to 45° S. of W. Another house close by gave a fairly good azimuth from 30° N. of W. One near the church gave a N. W. and S. E. azimuth. The two S. W. azimuths may be the result of some reflected or secondary wave , possibly derived from the spine like Monte Garofalo. If we exclude these and combine the rest, we obtain a resultant of 47° 30' W. of N. Or were we to combine the whole of these , excluding the two S. W. ones , the resultant would pass right through the seismic vertical. At Fiaiano ,

the Casa Baldino, marked Maisto on the map, is completely ruined, that is to say, it will require entire rebuilding. I noticed that the old fissures of 1881 played a very important part in the present destruction. The fissures are certainly very complex , and it was difficult to decide on any azimuth with certainty as there were two classes of injuries ; but the principal seemed to be from about 45° N. of W. Besides this, the ceilings and floors. some of which had collapsed , were much damaged in some parts of the building where the results of oscillatory motion were poorly marked.

Many other houses in Fiaiano were ruined or seriously injured : but from one only could an azimuth be obtained, which was from 20° N. of W. ; taking the mean of this and that afforded by the Casa Baldino , we obtain a value of 32° 30' N. of W. The remainder of the building seemed to be injured chiefly by a vertical shock ; as was indicated by the fall of many roofs and ceilings.

Looking at the group of houses that constitute the hamlet of Fiaiano, one cannot but be struck by the severe injuries it has suffered, out of all proportion to its distance from the seismic vertical. If we were to include it in the isoseismal area to which its injuries qualify it to belong, we should produce a markedly deformed curve; but, as both the inner and outer ellipses do not show any corresponding irregularity, we must look to local circumstances to explain the abnormal effects. In the first place, the houses are all constructed of loose trachytic scoria derived from the eruption o A. D. 1302, and combined with scant admixture of mortar, so that the cohesion of the walls was but very imperfect. As a consequence many of the ruins were reduced to heaps of volcanic cinders, little of which showed actual incorporation of the different constituent elements of the building materials. Again, not only do we find that different rock formations encounter one another in the vicinity, but we discover also that the hamlet itself is built on the edge of the crater of Cremate, from which the Lava del'Arso issued in A. D. 1302; and as we shall see when discussing the isoseismals, conduction along the old volcanic leader, as at Fontana, seems to account for the vertical shock which injured the ceilings, etc.

The church of S. Antonio was slightly fractured along the roof , but indicated nothing of importance.

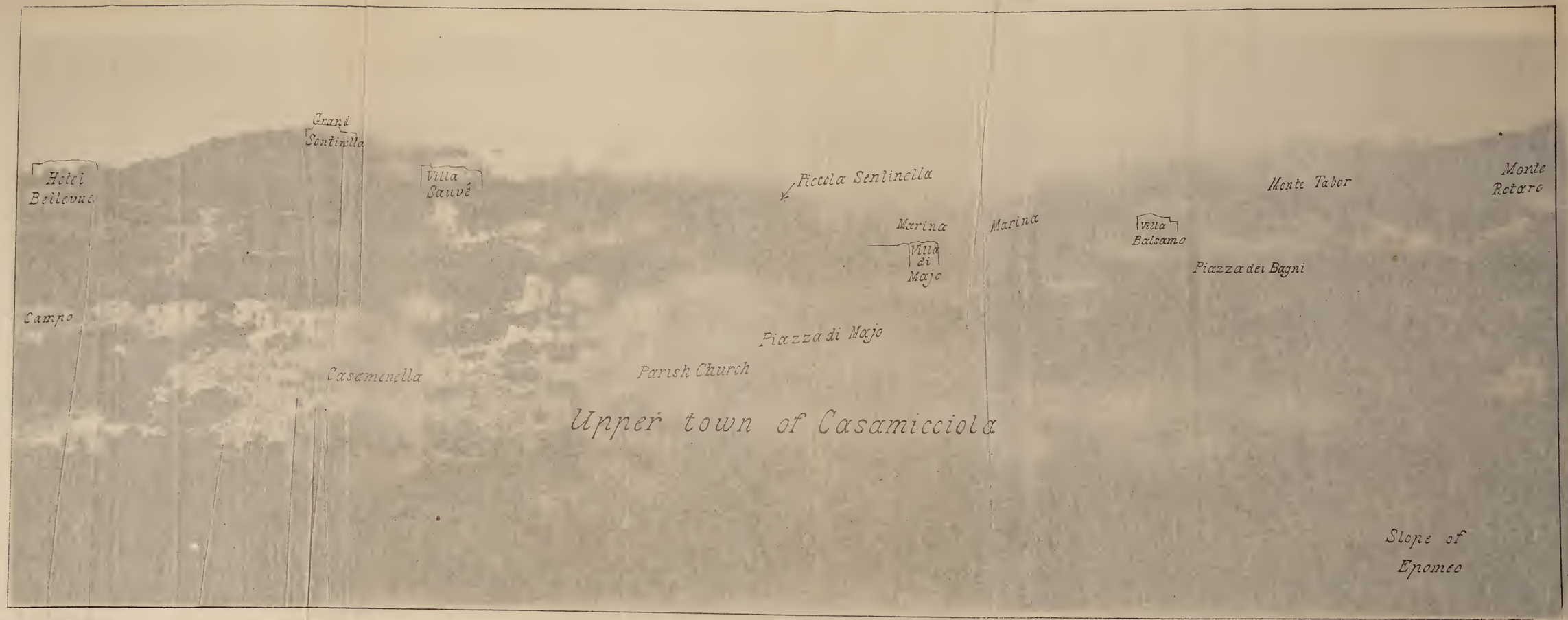
The town of Ischia felt the shock very distinctly , and a few houses were slightly cracked. The Castello , which crowns an isolated boss of trachyte , holds the same relative position as the mountain towns do in Mallet's diagram of Earthquake shadow, where the shock would pass beneath the place. In this case experience fully confirmed the anticipations of theoretical reasoning , for it is said that none of the garrison perceived the shock , whilst in the town itself it was distinctly felt.

At Bagno, or Porto d'Ischia, a few houses were cracked; but nothing of any definite character could be gathered.

65. The group of houses that occupies the irregular triangular space

between the slope of Epomeo and the crater cones of Montagnone and Monte Rotaro afforded some interesting observations. The little chapel was severely fissured and indicated a wavepath azimuth from 5° N. of W. A neighbouring house afforded an azimuth from 30° N. of W. and an angle of emergence of 38°.

The Casa Rotaro itself gave an azimuth from 5° N. of W., and a somewhat doubtful angle of emergence of 35°. The resultant of these azimuths is 13° 20' N. of W.



Panorama of Casamicciola from near Frasso, looking nearly N.
After the earthquake of July 28th 1883.

H. J. J. L. Phot.

Fotolip F.lli Doyen Torino

Panorama of Casamicciola from near Frasso, looking nearly N.
After the earthquake of July 28th 1883.

CHAPTER VII.

The Azimuths of wave-path, the seismic vertical, and epicentre (1)

The chapter on the geology of the island and the remarks on the construction of the houses will have prepared the way for the consideration of the wave path azimuths. Had the seismologist in the field to deal only with buildings of uniform texture and form, built upon a homogeneous soil, his work would require little attention, and the deductions from his observations would present but slight divergence from actual fact. As, however, such favourable circumstances can practically never exist, let us proceed to investigate the cause of that want of uniformity which characterizes to so large an extent our observations on the Ischian earthquake. We have seen how widely the various rocks that enter into the composition of the island differ from each other in structure and mode of distribution. Under such circumstances the seismologist is continually encountering difficulties. He finds for instance buildings in which there are two, three, or more groups of fractures, the one set often modifying the others, so that he is obliged, at last, to give up the locality in despair. Even supposing that he thoroughly understands the influence of reflected shocks, the presence of a hidden dyke or plate of trachyte, perhaps only a few yards from the surface, might, from its being unknown, quite confuse his calculations. This is so much the case with all volcanic regions, that they will always present much greater obstacles to seismological investigations than will districts composed of regularly stratified sedimentary rocks.

The varietes of stone, brick, and mortar employed, the difference of style in buildings, the various forms houses assume, and the fact that the walls

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(1) See Plates III, and IV.

both inside and out are covered with plaster, render deduction of azimuths most wearisome work , giving most unsatisfactory results.

In large areas, towns may afford a series of azimuths, of which each individual one may be erroneous; yet the mean resultant will not be very far from the truth, and there will be little danger of their being wide of the seismic vertical. In such a case also we can often pick and choose our buildings for observation, so that the error arising from each is likely to be diminished. When, however, we have to deal with a small area, such as that affected by these two earthquakes, we are reduced to the necessity of making use of as many buildings as possible, often having to choose, indifferently, those situated on steep slopes, on over-hanging escarpments, or whose walls may be directed to any point of the compass; not to speak of their possible complexity of plan and structure. Neither is it an easy matter to separate the damage due to the direct wave from that arising from the transverse one.

Last, but not least, we must remember that the source of earthquake movements is not a mathematical point, but a fissure of considerable area, no doubt of very irregular form, and the formation or enlargement of which may have followed an irregular course, so that the isoseismals may assume figures equally irregular.

These facts, combined with magnetic errors of the compass, are the cause of the wide divergence from the point of orientation which is observable in the maps of both earthquakes.

There are however one or two groups of observations which it is right we should pause for a moment to consider.

The area that is bounded by a line drawn from the Casa Manzo or Nesbitt to the centre of Forio showed most of the buildings therein as injured by two groups of fractures, one set that would indicate an azimuth coming from the seismic vertical proper, and another from the mass of M^t. Marecocco and Zale. The second group of fractures seemed quite out of proportion to what was observable in other parts of the island as due to the transverse wave. Here, as already remarked, there is little doubt that this great boss of trachyte played the part of an important reflector; and it would seem that the effects of these reflections extend farther away from the mass towards Forio, where the direct wave struck the mass more obliquely, than at Lacco, where the direction of impingement was practically at right angles to the face of the rock mass; a result which accords exactly with what we should expect on theoretical grounds.

If we examine the group of azimuths of the 1883 shock between Panza and Barano, (Plate IV.) we find that the majority of them are remarkably abnormal , and that this abnormality is greatest at the two extremities of the area indicated , and diminishes as we approach the centre. Looking at the general features of Epomeo, we remark that its summit consists of an annular ridge forming some two thirds of a circle. The highest point of

this ridge is situated about midway between its extremities, towards which there is a gradual fall. The centre of maximum violence lies some distance away, but facing the culminating point of the ridge; whilst the district beteween Panza and Barano lies hidden behind this elevation, and distributed symmetrically in relation to the focus of the earthquake. So long as the wave path traverses no part of the ridge, as at Pezillo on one side or Piejo on the other, the azimuths remain normal: but so soon as the vibrations have to traverse part of this crescent ridge, the azimuths diverge widely from the seismic vertical. The greatest divergence is at the two extremities of the crescent, namely at Panza and Barano: as we approach the point midway between these, the azimuth becomes quite normal, as at Fontana; while at Serrara and Moropano the amount of error corresponds with their intermediate position.

At first sight, we might be inclined to suppose the cause of this abnormality to be the extension of the fissure as far as Fontana, or the existence of another centre of activity beneath that place. Such an explanation, however, would hardly be consistent with the arrangement of the azimuths, which are less erroneous towards the centre, or with the sudden transition from normal to excessively abnormal ones, which we find between places in such proximity as Pezillo and Panza on the one hand, or Barano and Piejo on the other, both in close proximity, respectively to one another. All these azimuths are taken in localities high up the mountain slope, and are therefore more liable to be affected by its physical conformation. A shock from Casamenella would encounter the centre of the ridge of Epomeo, perpendicularly to it, and would traverse it without marked deviation, thus explaining the azimuth of Fontana; but the centre of the ridge being nearer the seismic vertical and receiving the shock first, this would be communicated all along the ridge and would follow its curves, so that a kind of serpentine undulation would traverse it, vibrating at right angles to its curved axis. Hence the original wave path would have been much modified. The abnormal azimuths are mostly perpendicular to the tangent at that part of the ridge nearest to which they are found, and therefore seem to indicate such an origin. Of the two explanations here given, I prefer the latter, and although it must be admitted that it is somewhat hypothetical, the facts are more in its favour than in that of its rival.

A considerable number of the azimuths of the earthquake of 1881 (Plate III), converge towards an area, the centre of which is situated just W. of the junction of Casamenella and Campo, and indicate that spot as the site of the seismic vertical; while, to judge from their arrangement, they seem to have emanated from a fracture whose strike must be from a few degrees W. of N. to a few degrees E. of S.

To the extremities of this fissure or fracture, so far as we can judge from the azimuths alone, I should feel inclined to ascribe the following limits. Its N. extremity reaches about half way between the Forio road at Casamenella,

and the upper part of Lacco, whilst its S. one reaches to very near Frasso. The point of maximum violence, it will be seen later, was somewhat, though very slightly, nearer the N. extremity. This corresponds almost exactly with that described by Covelli in the earthquake of 1828, although he adopted no scientific method whatever of investigation. When I made my map of the 1881 shock, I had not yet studied the literature of the subject; and I was much struck by the similarity in the results obtained by two observers so widely separated in every way.

In the azimuth map of the 1883 earthquake (Plate IV), we have the most striking confirmation of the fact that all these shocks emanated from practically the same focus. In 1883 a still larger number of azimuths converge towards the same area as that indicated in preceding earthquakes. Though, however, the site of the lesion (or fracture before mentioned) seems to be much the same in 1881 as in 1883, there is a vast difference in its extent, it being larger in the more recent than in the earlier earthquake. In the later catastrophe I am inclined, from a study of the various injuries inflicted, to place its N. extremity near the road at the upper part of Lacco, while, towards the S., it may have extended as far as, or even beyond, Frasso. The centre of maximum impulse seems to be nearly the same as in 1881, although it may be very slightly nearer the Forio road, or more to the S.

CHAPTER VIII.

Angles of emergence and mean depth of foci. (1)

Much that has been said with regard to azimuths of the wave path is applicable to the angle that the emergence of the latter forms with the horizon.

The irregular distribution of rock masses differing in form and density, the uneven surface of the ground and want of uniformity of construction in the various buildings examined, all render the observation of angles of emergence even more difficult than that of simple azimuths. Probably the greatest error, however, arises from the fact that the focus in this case is not a mathematical point, but probably a fissure, whose area is large compared with that of the district in which observations are made. Besides this, in calculating the mean depth of the focus, we are obliged to employ a vertical line instead of a plate-like area, a form which the fissure probably assumes, and the size of which is only approximately known.

The observations taken in 1881 were so scanty that hardly anything more than a rough guess at the depth of the focus could be expected, and even the observations of 1883 are really small in number for the purpose required.

One fact worthy of notice in the azimuth charts is, that the farther we recede from the seismic vertical, the shallower is the focus indicated by each observation, or in other words, the angle of emergence diminishes more rapidly than it should do in proportion to the distance. The explanation of this apparent anomaly, it seems, is not far to seek. The farther we descend below the earth's surface, the greater will be the superincumbent pressure, and the greater

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(1) See Plate V.

the density of the rocks and the more water-logged will they be. This would be more marked in such a very compressible substance as the Ischian tufa. Now a wave path, starting from the focus and extending up towards the surface, will suffer refraction as it passes from the denser to the less dense medium; and as the angle of emergence diminishes, so will the refraction increase. But as the wave path passes from a dense to a less dense medium, it will be refracted from the seismic vertical, and the true path will assume a curve, whose convexity is upwards, so that the observed emergence will give less than the true depth for the focus. The lower the angle of propagation, the greater the refraction , so that distant stations will yield the largest error (*).

The angles of emergence afforded by a second or third earthquake in one region , are often higher than they should be , as former shocks may have already fractured the walls at a certain angle ; and the subsequent shock, although it may come from a focus nearer the surface, will enlarge the original fractures , which , as a consequence , will still indicate the emergence of the wave by which they were originally produced. This irregularity was often illustrated in 1883 , where old fissures , that had been but small cracks in 1881, hardly recognisable, or large ones that had been filled in with plaster , were re-opened by the later shock. In some houses , as in that of Mr. Nesbitt , the fractures of 1828 , 1881 and 1883 were all to be seen.

We may attribute the wide divergence of the lines (Plate V.) indicating the emergence of the wave paths to the same causes that affected the azimuths, and of course to this we must add the effect of refraction already spoken of. It is also probable that some of the oblique fractures in buildings were aggravated , if not in some cases caused , by the foundations resting on soil of heterogeneous nature ; or more often near the edge of an escarpment or steep slope.

There are six observations of emergence of the 1883 shock (Figure 2, Plate V), that differ most markedly from any others, in the great depth at which the wave path would encounter the seismic vertical. Now these six observations are just in that region where we found a corresponding abnormality in the azimuths, and in fact many were taken from the same building which afforded those azimuths. An attempt at an explanation would require a complete acquaintance with the subterranean geology of the region, which is impossible, and a knowledge of mechanical problems that but few would dare to handle; still I am inclined to regard this as the consequence

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(*) Prof. S. Haughton writes to me saying he thinks the difference of density would be infinitesimal.

of refraction or reflection, rather than as arising from a focus beneath Fontana; for the following reasons:

The corresponding azimuths do not indicate any point as another seismic vertical ; the angles of emergence do not follow any gradation , as we approach, or recede from, the hypothetical seismic vertical, all of them ranging within a few degrees, although the difference in the distances of the stations, one from another, is very variable. I calculated however the mean depth of a supposed focus beneath Fontana , and obtained as the result , 475 metres below sea level, or a difference of 53 metres less than the mean depth beneath Casamenella. Now it is certainly a remarkable fact, that the focal depths are nearly the same distance beneath the sea level and would rather favour the existence of a second centre of disturbance beneath Fontana. That this is not the result of the continuation of the fissure from Casamenella to Fontana is distinctly proved , not only by the intermediate observations , which indicate no such vertical movement as they should do in such a case, but also by the arrangement of the azimuths and isoseismals, which exclude such an hypothesis.

Calculating the mean depth of focus for the earthquake of March 4th. 1881, we obtain 518.25 metres from the sea level, or about 618 metres beneath the surface at Casamenella.

For the earthquake of July 28th. 1883 , the calculation of the mean focal depth affords 528 metres below sea level, or about 628 metres below the surface at Casamenella.

This is of course exclusive of the six observations already discussed , on the S. side of the island. We are justified in so excluding them for two reasons; first, because they are obviously erroneous , or belong to another centre of propagation ; and secondly, because we have none for 1881 with which to compare them.

Although we should have expected the last earthquake to have emanated from a focus nearer the surface, if both are due to a fissure filled by igneous matter which is extending itself upwards, yet the slight difference between the results obtained from two groups of entirely different observations is extremely remarkable. That with so many errors of observations there should be only a difference of some ten metres so astonished me, that I went over my calculations again , endeavouring to detect some error, but without success.

We have every reason to believe that the lesion which gave rise to these earthquakes has on each occasion approached nearer towards the surface, and, if such is the case, the error of which we have spoken must be greater than it really appears to be , having apparently reversed to a certain extent the relation in which the two mean depths stand to each other.

It is therefore not possible to determine the actual extent to which the fissure was enlarged upwards, although the study of the azimuths, the extent and form of the mesoseismal area, and the form of the isoseismals indicate

a marked enlargement in the plane of its strike, i.e: towards the beach of Lacco and towards Epomeo. It is hardly possible , therefore , to conceive that it did not extend in a direction, where the least amount of resistance would be met with: viz: upwards, We have no direct methods for calculating the focal depth of the shock of 1828 described by Covelli ; but from its small extent, and many other points of similarity with the two important shocks which followed it, we may conclude that it also had its origin remarkably near the surface.

CAPTER IX.

The isoseismals, and further remarks on the form of the focal cavity. (1)

It will be convenient to commence with the earthquake of 1881, since that is the first in which we have anything like exact bases to go upon , and also because the whole of the affected area rests on no more than two geological formations, very similar as regards their influence on mechanical vibrations,

In the centre of the injured district we have a mesoseismal area in the form of a band, running nearly N. and S., extending through the W. part of Casamenella and Campo. The damage inflicted on the buildings included within this band was very characteristic of the nature of the shock; the walls having received but slight injury , whilst almost every floor and ceiling had been totally destroyed. In fact many houses would have required no other repair than the replacing of the divisions between the different stories : that is to say , the houses , to use a fireman's expression, were « gutted ». This mesoseismal area (in which we have distinct evidence of a vertical shock , or where the angle of emergence was near, or at, 90°) must lie along the surface above some focus of energy , whose plan must assume the form of a vertical plate-shaped fissure , striking in the same direction as the area of injuries due to vertical shock , or from a little E. of S. to a little W. of N. The extremities would be near Frasso , on the one hand , and at a point midway between Campo and the upper part of Lacco, on the other.

This mesoseismal area gradually fades off into the district I have included within the curve of the first isoseismal, where those buildings are situated

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(1) Plates III, IV, VI; Photos. I, XI.

which had suffered almost total destruction , and all of which should have been rebuilt. This isoseismal will be seen to assume an elliptical figure , the major axis of which is directed from a few degrees S. of W. to a few degrees N. of E. In the formation and forcible injection of a fissure, the greatest impulse will be perpendicular to its faces, so that the wave curves will tend to assume an elliptical form with the fissure for their minor axis. This fact was pointed out long since by Mallet (1), although Prof. de Rossi of Rome has lately laid claim to its discovery.

From the strike of the major axis of our isoseismal, we should obtain that of the minor one, or in other words the position of the focus. By this method, although the strike of the fissure corresponds with the minor axis of the ellipse, yet its position does not, for the mesoseismal band is nearer the E. end of the isoseismal. As contributing to determine this position, we may mention one agency, if not two. First the E. end is on the marl-like tufa which, from its slightly lower elasticity, would less readily conduct the vibrations in that direction or would absorb them more rapidly. Secondly, I am inclined to fancy that the plane of the fissure leans to the E , or in other words dips to the W. so that the earth-waves would be directed downwards and away from the surface on the E side, and upwards and towards the surface on the W. (2).

This first isoseismal line cuts the Piazza di Majo on the E., and extends to the junction of the road to S^{t}. Aniello with that to Forio, on the W; it includes Frasso on the S. and Pannella to the N.

The second isoseismal much resembles the first in form and relative position. It is intended to include the area in which most of the buildings were almost completely destroyed, or suffered very marked damage. It includes Villa Barbieri , Torre , passes near the Annunciata , cuts the upper part of Lacco, including Casamonte , and Calasisto, and passes just E. of S. Maria delle Grazie. Its S. limit is somewhat problematical , as the steep slopes of Epomeo are uninhabited.

The third isoseismal also assumes an elliptical form. It marks the region in which the buildings were severely fissured. It includes the Villa Maresca , passes into the sea at this point to strike the coast again at the Marina of Lacco , passes through the Villa Arbusto , takes in a bit of the sea, N. of Forio, cutting that town and embracing the district of Monterone. It then probably sweeps round and includes Monte Pellero , Toppo (3) and Buceto.

Two localities however have been left out , namely Fontana and the Casa Baldino or Maisto at Fiaiano.

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(1) The Neapolitan earthquake, Vol. II, p. 267.
(2) Mallet ibid. Vol. II, p. 269.
(3) Not Lo Toppo.

Fontana was injured to an extent quite out of proportion to its distance from the seismic vertical. Not only so, but its injuries (page 61) indicated that the shock which damaged it issued from the ground in a vertical, on nearly vertical, direction. As an additional proof of this may be cited the statement of the inhabitants, that they felt first a violent subsultory shock, followed by a feeble lateral one from the N. Here then we apparently meet with an indication of another seismic centre! Although such a thing is not impossible, or even at all improbable, still I am inclined to adhere to the explanation I have given of it on a former occasion (1), which I quote here :

« We have in one earthquake two seismic verticals. One surrounded by « a district in which the damage diminishes more or less gradually, as we « recede from the mesoseismal area; in the other, we have a small mesoseismal « area surrounded by districts quite or nearly uninjured.

« The following explanation has appeared to clear up the difficulty , « and perhaps I may be permitted to give it.

« As already stated, Fontana occupies the centre of the great crater of « Epomeo (Plate VI), and therefore lies immediately over the ancient « chimney, which in all probability is filled by an old plug of consolidated « trachyte , which must descend to the igneous reservoir. Any mass of « igneous matter, that might determine the further rupture of a collateral « fissure , would result in the conduction of any changes of pressure or « vibrations, along the column of highly elastic trachyte ; whilst the same « earthwaves would be annulled or absorbed by the inelastic tufas surrounding « it, so that the blow would be struck perpendicularly to the surface, and « in a small area with well defined limits. The undulatory sensations, after « the principal local shock, were those that arrived from the great centre « of impulse beneath Casamenella ».

At Fiaiano, the damage was also very great in proportion to its distance from the focus. Now, in speaking of the azimuths, I showed that this might be due to the contact of two or three different kinds of rocks. We observe also that the hamlet is built on the very verge of the crater of Cremate, from which issued the lava stream of 1302. Now we have undoubtedly a column of trachyte filling the old lava chimney, which must extend directly down to the reservoir of igneous matter. It seems to me, therefore, that this column conducted the vibrations more readily to the village of Fiaiano, which is built upon and close to its upper extremity. We have therefore , a repetition of the condition at Fontana, where, however, the existence of a column of trachyte is hypothetical, whilst the injuries due to vertical shock are well marked. At Fiaiano we have positive proof of the conducting

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(1) British Association Reports 1883; Nature, August 9th, 1883. Vol. XXIII; and Notices on the Earthquakes of Ischia 1881 and 1883—Naples 1883.

medium, but the evidence derived from injuries does not especially indicate a vertical shock; and I should have hesitated to give the above explanation, were it not that in 1883 the destruction of the floors and ceilings was well marked, and that the sensations of the inhabitants pointed to subsultory, followed by undulatory, movements, the former predominating.

It is observable that the mesoseismal area exactly corresponds with that described by Covelli in the earthquake of 1828, and that in both of these, as in the third earthquake, we have a secondary centre at Fontana. The description of the earthquake of 1828 is so remarkably accurate, so far as detailed observation goes that it is astonishing that recent authors should have so neglected it.

The area over which the shock of 1883 was felt is far greater than that affected by its predecessors. The mesoseismal area assumed the same form, as in 1881; but was of wider extent. The band of maximum vertical destruction extended from S. of Frasso, to near the centre of the upper part of Lacco, and close to Casamonte.

The first isoseismal of 1883, like that of its predecessor, assumes an elliptical form, and roughly corresponds to, though it is slightly smaller than, the third isoseismal of 1881. In this we include the area of total and complete destruction.

Passing from the Villa Vedova Manzi it enters the sea near the outfall of the Ombrasco rivulet, crosses the Punta del Pozzo, divides the upper from the lower part of Lacco, includes Mezzavia, S. Michele, the Vajola, the E. part of Monterone, S^{ta}. Maria del Monte, then probably passes just N. of the Monastery of S^{t}. Nicola, and then, bending round, it includes the district of La Tresta. The second isoseismal includes the area in which the damage was nearly complete. It assumes a much more circular form than the others hitherto observed, and the whole of its W. half almost exactly corresponds with geological boundary lines, so that it seems highly probable that it owes its form very much to that cause. It passes just beyond the Villa Maresca and then enters the sea, which it quits at the Marina of Lacco, cutting that town, but including the greater part of it; it then roughly corresponds with the boundary line between the compact Epomeo tufa and the trachyte of Zale, and Monte Vico, and the loose tufas of the latter. It cuts the town of Forio in a line almost exactly corresponding with the junction of the compact tufa, and an alluvial brecciated tufa. It enters the sea again to join the land near the road of the Monte Imperatore, from which point to near Barano it is parallel to the line of junction of the compact Epomeo tufa with the more recent loose trachytic variety. Panza, Serrara, Maropano are all included within it. It traverses Barano at the junction of two varieties of tufa, and then sweeps round, taking in Piejo, Fiaiano, and Rotaro.

The third isoseismal, bounding the area of distinct or marked injury, is very problematical, from the difficulty of fixing the portion on the land, and the impossibility of defining its limits in the sea. As far as I can judge

it is nearly circular. It seems to cut the Porto d'Ischia, to divide S. Antonio from Campagnano, to pass into the sea near Monte Vezza, and only to touch land again at the extremity of Zale between Punta Caruso and Cornacchia.

One point that holds good in both earthquakes, is that the isoseismals approach each other to a great extent exactly opposite the N. extremity of the plan of the fissure. Such a condition it seems could only arise from one cause, namely, that the axis of propagation upwards of the fissure dips to the S. Now we have already seen that the plane of the fissure dips to the W.: we may therefore say that, as a whole, the fissure extends from below upwards in a direction that is not vertical, but directed a little to the N. and E. As a consequence of this, should the existing lesion extend to the surface by future ruptures in its present direction, we should expect the eruption to take place a little N. E. (roughly) of the present mesoseismal area, or somewhere near the district of Campo.

While discussing the different regions of the island affected by these earthquakes, we may conveniently consider the extreme limits at which they produced any sensation, or were registered by suitable instruments. The shock of March 4th. 1881 was felt distinctly by many people in the island of Procida. I visited that island and made inquiries of a great number of people, selected chiefly from among the priests and the more educated part of the inhabitants. From their evidence it would seem that at least a third of them remarked the earthquake at the moment, and many remembered some disturbance when they were afterwards made aware that an earthquake had occurred in the neighbouring island. Along the opposite coast at Monte di Procida, Misenum, and at Bacoli, the earthquake was slightly felt. So rapid was the absorption, that the seismographs at the University of Naples and the Vesuvian observatory registered no movement. As this was one of the facts upon which Prof. Palmieri based his refusal to accept the theory that the movement was the result of a true earthquake, it is worth considering the reasons why such a small area was affected. Supposing we have to deal with the earth as a homogeneous medium, then an expenditure of energy at a depth of five kilometres would have to be ten times as great to produce a given affect at the surface as it would were it placed only half a kilometre from the surface, as was the case on the present occasion. Now the deep focus would produce very little less effect at a point ten kilometres away from the seismic vertical than at the epicentre itself, as it would have travelled a distance greater only, roughly speaking, in the ratio of 14 to 10. On the other hand, were a blow delivered at a depth of half a kilometer only, sufficient to produce near the seismic vertical, damage equal to that resulting from the deeper centre, the effects of the former at ten kilometres distant would be very inferior to those of the latter. For the distance from shallow focus to the distant station, compared with that from the focus to the epicentre, would be greater in the ratio, roughly speaking, of 20 to 1. In other words the effects produced at the distant station by the deep focus would be less than those produced

at the epicentre by only $^{2}/_{5}$; whereas in the case of the shallow focus they would be less by $^{19}/_{20}$. In the latter case, the absorption of vibrations would have gone on to such an extent that at a little greater distance no observable effects could be produced. It is with just such a case as this that we have to deal at Casamicciola, where we have a feeble expenditure of energy very near the surface; so that its effects immediately over that point were very marked, while they were not sufficiently strong to show themselves at any great distance. Not only must we consider the small amount of energy expended at the focus of these small earthquakes, but we must remember the effects of geological structure and of physical configuration. We have reason to believe, from observations of the artesian wells in this region, that the older sedimentary rocks of this district are covered by a deposit of volcanic tufas of from to 300 metres in thickness. These tufas are largely composed of pumice , are but imperfectly coherent, and the component elements are of most variable density and elasticity, so that an earthwave, however powerful, would undergo great absorption in every foot of its transmission through such a material. Again, we must remember that the different strata of volcanic materials of which it has at various periods been built up, dip in every imaginable direction, so that the vibrations would be reflected and refracted at every few yards. If we connect either the Neapolitan or Vesuvian seismic station , by a straight line, with the volcanic focus, we shall find that an earth wave, to reach either, would first traverse the rock of the island, would then enter the sea , and would subsequently emerge into the air , to be transmitted immediately to the instruments , or to again enter the earth. Such a variety of media interposed, would be quite sufficient to annul even very violent earth movements. In other words, both of the above mentioned stations are in what Mallet has denominated « earthquake shadow ».

On July 28th 1883, at about the same hour as the shock at Casamicciola, a slight disturbance was felt by the inhabitants of some parts of Naples, and two shocks were registered by the seismographs of Naples and Vesuvius. Now had it been possible to obtain the correct time of the shock at Casamicciola, we should have had apparently good data for calculating the velocity of transmission, etc. But we must remember that the shock registered at these stations may only have been accidentally coincident with the earthquake in Ischia, or may have been a seismic wave that was the determining cause of the local fracture. This seems proved by the fact that the shock of the night between the 24th and 25th of July of 1880 was strongly felt and registered in Naples, but only frightened the Ischians , and did no damage at all. A week after the great catastrophe of 1883, a very decided shock was felt at Casamicciola , but beyond bringing down a tottering wall or two , was of little importance ; yet it was as distinctly marked at the above mentioned seismological stations, as had been its great predecessor. How , therefore , are we to believe that these movements, which were made evident at Naples and Vesuvius, were transmitted from the focus beneath Ischia ? I think we

are compelled to regard them as more general in their origin and distribution, and only in certain cases the determining cause of a local display of energy; that is to say, in certain cases, such a movement was « the last straw on the camels back ». It might have been argued, that this fact of earth movements being felt in Naples on July 28th 1883, was simply the result of greater force in a deeper focus; but, certainly, an increase of focal depth of only 10 metres puts such a hypothesis out of the question. Were these registered shocks really derived from Ischia, we have the explanation of them in the greater violence of the earthquake of 1883 as compared with that of 1881.

We have just stated that the two observatories of which we have spoken are in the earthquake shadow with regard to Casamicciola; this fact would at first sight appear inconsistent with the supposed transmission from the Ischian focus. Yet, theoretically, the disturbance of the instruments would be possible, on the supposition of the wave being in some way so reflected or refracted as to reach them in an indirect manner.

The earthquake of 1883 was distinctly felt at Procida, Vivara, the Ponza islands? and the main land opposite, as far, it is said, as Pozzuoli.

CHAPTER X.

Various phenomena accompanying the earthquakes, or related to them.

There are several phenomena coincident with the Ischian earthquakes that will repay investigation.

Nearly all earthquakes of any intensity are accompanied by a noise of some kind. Those of Ischia are perhaps remarkable in this way, for often a slight shock is detected more by a subterranean thundering accompanying it, than by the actual movements felt. A resident at Barano told me that some years since, at Testaccio, a muffled report, coming from beneath, could be heard regularly every quarter of an hour. He also declared that this phenomenon is very common in that locality, and often lasts for many weeks. I have heard others affirm the same thing.

In the great shocks of 1881 and 1883 this noise has been described as a muffled rumble (cupo rombo), as the passage of wagons, the report of artillery, the rattling of chains and as distant thunder. All these descriptions give us the idea of a series of muffled reports or rumbling, with the exception, however, of that of the rattling of chains: a simile, which I believe (from what I have learned by inquiry of those who have used it), owed its origin rather to falling masonry, or to the displacement of loose objects close at hand. The description given by the proprietor of Perrone, of the noise in 1881, has often been repeated in almost every detail by others after the shock of 1883; that is, as a series of muffled reports following each other, at first rapidly, but with gradually increasing intervals between them. Such a noise we might well expect to accompany the formation of a large fracture by successive steps, which would take place with greatest violence at the first moment, but as the space given to the expanding matter increased, the rending power of the latter would diminish. The deep muffled

and irregularly marked character would be the result of the medium traversed, and of the secondary waves generated.

Those who were near the epicentre describe the sound as being simultaneous with the movements; whereas those further away were able to distinguish the sound before the shock of earthquake. From this, it would seem that acoustic vibrations travel faster than simple mechanical ones.

The actual earthquake itself was described as subsultory, only by those who were in the mesoseismal area ; as subsultory and undulatory or oscillatory, further away, as also at Fontana and Faiano; whilst, towards the limits of the injured area, only the oscillatory movements were discernible. In the neighbourhood of Zale , at Forio , and many other localities , the so-called vorticose movement was declared by many to have been felt by them. The only explanation of this is the arrival of two shocks in different directions , at very short intervals : as is indicated by the rotation of the columns of the Via Roma in 1881 , and the pilaster caps of the Villa Gastaldi in 1883.

So far as we know, a moderate period of complete inactivity seems to have preceded the destructive earthquake in the island; though in 1883 it is stated that an artist of the name of Richer had noticed his watch , which was hung on a nail on the wall, swing at 6 a. m. on July 24th, and that, on returning from the bath at 9 a. m., the watch was again in movement. This he mentioned to his companions; who, however, laughed at him. This is the only precursory-sign, if it be worthy of the name, that I have been able to ascertain ; unless I except certain changes which are asserted to have taken place in the condition of the thermal waters.

Of this latter group of so called forewarnings, there was an unlimited supply, but my own investigations lead me to the positive conclusion that most of them, if not all, were without any foundation in fact.

Covelli gives distinct scientific evidence of no important change whatever before, at the time of, or after the earthquake of 1828 , except a possible temporary elevation of temperature at the source of the Acqua della Rita , which is situated very close to the epicentre. In 1881, on the morning of March 4th, a woman went (according to her daily habit) at about 10,30 to bathe a crippled arm in the water of this same spring , but to her astonishment the temperature was unbearable. She left the place somewhat frightened, and had arrived in the vicinity of Calasisto when the earthquake took place.

It was said that the thermal springs had gushed forth, boiled, changed colour, and become muddy—that the fumaroles had burst out with violence, and that even flames had been seen. I arrived in the island 24 hours after the shock , and within the next 24 examined most of the localities where such phenomena were declared to have occurred ; but could find at the time of my visit no remarkable change , nor any signs of such having

occurred. The subsequent analysis of the waters by Zinno showed no change whatever in their mineral constituents.

It is asserted that on the day previous to the earthquake of 1883 the water of Gurgitello became much hotter than usual. Now Fuchs and others, who have thermometrically examined the Ischian waters and fumaroles, have demonstrated that the temperature of these may vary within wide limits without such change being followed by an earthquake; and it is a well known fact that the Gurgitella waters present a difference of temperature of as much, sometimes, as 30° or 40°

It was also stated that the wells of Casamicciola dried up; but as most of these so-called wells turned out on examination to be cisterns, it is difficult to see how this drying-up could occur before the earthquake, unless it were caused by the owners drinking the water or otherwise using it. There are two real wells, however, whose water level was proved to have in no way changed.

In the district of Vajola of Forio was a celebrated well of potable water, which seems to have been slightly altered towards the end of July and the early part of August. I give here a translation of a note sent by Signor Bonaventura Verde, together with a specimen of the water, to Prof. Palmieri.

« In the district of Vajola to the east of Forio, a place well bombarded « by the earthquake of July 28th, there is a rather deep well which has « always afforded plenty of the best drinking water, renowned for freshness, « limpidity and flavour. This spring, 8, or 10 days before July 28th, not only « began to diminish, but also became less fresh and more turbid, so as « to have acquired the colour of water in which macaroni has been cooked, « and to have developed a pronounced odour of Sulphuretted hydrogen, and « a disagreeable taste; and in short to have become unfit for use.

« Ten days after the catastrophe of July 28th, in a short time, the water « under examination lost its bad qualities spontaneously and again became « abundant, fresh, limpid and of pleasant taste, and all the people of the « district made use of it for all kinds of purposes, especially to drink, in « the same way as they employed it before.

« Seven or eight days after this, the same water again lost its good « qualities and returned to its bad state as on July 28th. To make the « matter clearer, I send you a bottle of it.

« These facts were recounted to me by the owner of the well, and « the inhabitants of the neighbourhood, I therefore, when revisiting the « locality, wished to fill with my own hands the bottle which I send you.

« The same people who gave me the above observations assured me « that the same things occurred on March 4th 1881; that is to say, that « shortly before that date, the water of the well of which we are speaking « was good and potable, and in a short time became bad; and again after the « earthquake returned to its former state of excellence.

« I remain etc. etc.

Bonaventuro Verde

It appears that the evening after there occurred two slight shocks, and the water again became clear. Prof. Palmieri believes that some fumarole communicates with the well, and that this, becoming more active before the earthquake, saturates it with Sulphuretted Hydrog en.

This seems to be the best authenticated example of any well being affected contemporaneously with the occurrence of earthquakes; but as it stands alone, it can hardly be taken as proof of the volcanic nature of the shocks in the island.

Prof. Oglialoro in his report (1) shows that considerable variation took place at different periods after the earthquake in the fumaroli of Monte Cito; but whether these variations are normal in that locality has yet to be proved.

Some authors who have written on this last earthquake have placed the seismic focus exactly under the lowest fumarole of Monte Cito, forgetting that, although the series of these fumaroles may occur along the upward extension of the fracture which is the focus of these Ischian earthquakes, yet there is every reason to suppose that the passages for the vapour are very irregular and sinuous, and that there exists no justification for fixing the focal centre any nearer than within half a mile on either side of them. Nevertheless, it is worthy of remark that the axis of the fissure, or earthquake focus, is nearly on a line joining the most active fumarolic area of the island with a mass of decomposed tufas, resulting from the same action on the beach of Lacco; a fact which would seem to show that the rupture was taking place along an old line of weakness.

Perhaps one of the most interesting phenomena accompanying the Ischian earthquakes, and sometimes taking place spontaneously without their aid, is the occurrence of landslips, and the detachment of rocks. Anyone who rambles over the northern and eastern slopes of Epomeo and the corresponding part of the island, meets with these gigantic masses of compact tufa which from time to time become detached from the crest above and dash headlong down through forests and vineyards, carrying away or cutting down everything before them. From the great abundance of these, the eastern flanks of Epomeo have the most ragged and ruined appearance, and may well suggest the efforts of the buried Typhœus to free himself by upheaving and ruining what must once have been an elegant truncated volcanic cone.

From the short account of the disaster of 1228, it would appear that much more damage was due to a landslip and avalanche of stones, which resulted in the destruction of 700 persons, than to the earthquake,. In the year of 1797 on Dec, 14th at 10 p. m. in the vicinity of Catreca, at two

(1) Atti della Reale Accademia delle Scienze Fisiche e Matematiche di Napoli. Vol. I, Serie 2,ª

different points, a great landslip took place which severely injured the vines near Casamicciola.

Siano, who describes this, speaks of another, a few years before his time, that took place near the same locality. Both of these seem to have occurred independently of earthquakes.

The great shock of 1883 was destined to be the determining cause of three, or at least two, distinct landslips on a grand scale (see Photo. XX).

The first two of these, though apparently separated by an undisturbed piece of ground, are really due to the same causes and occurred under identical conditions. They had their origin, one in the steep part of the N. slope of Epomeo above Fango, and the other in the district included between the buttresses of M^t^. Bastia and M^t^. Nuovo. The materials in which this occurred consist partly of an old talus of detached blocks of Epomeo tufa, and partly of the tufa rock itself. An examination of the constituents shows them to have been to a great extent exposed to fumarolic action for a number of years; as is proved by their variegated colour, the deposit of amorphous silica, and their decomposition into powdery and clayey materials, which were kept in place by the covering of vegetation. The great heats of June and July had dried up the undergrowths and cracked the surface, thus to a great extent destroying the cohesion of the mass and its power of sustaining these loose unstable materials. The earthquake was the determining cause which brought down these two avalanches of rock fragments, carrying the trees of the chestnut forest away with them, tearing up and burying large numbers.

The other landslip happened on the flanks of M^te^. Rotaro. The. S. W. slope of this cinder cone is separated from M^te^. Buceto by one of the branches of the Ombrasco ravine, which at this point is very deep. The Buceto slope is composed of the marl-like tufa, while the Rotaro side consists of the loose scoria, pumice etc. that goes to make up that cone.

From the incoherent nature of this latter, and the enfeebled support of superficial vegetation, a very extensive mass was detached by the earthquake and swept down into the gorge below, thoroughly blocking it up. The crumbling away of the raw surface continued, and even at present small landslips continually occur. Some weeks after the earthquake, when some torrential rains fell over the island, much of this material was swept out of the gorge, inundating the lower parts of Casamicciola with volcanic mud or « lava d'acqua ».

Landslips of the vineyard terraces and small scarps occurred all over the island, and in a great number of cases contributed not a little to the destruction of buildings constructed in their vicinity.

The steep cliffs of incoherent tufa between the Punta S. Alessandro and Punta Perrone, and again between the mole of Casamicciola and Lacco, had been very much damaged so that large quantities of their materials were thrown into the sea. The water then sorted out the pieces of pumice,

H.J.J.L.Phot. Fototip. F^lli Doyen Torino.

View of the two landslips above Fango from Mezzavia, looking about S. S. E. Panella is seen to the left.

which in many cases were of very large size, and were seen floating about in the neighbourhood for some days.

The morning after the catastrophe Dr. Eisig vice director, and M. Petersen, the engineer of the Zoological Station at Naples, were steaming in the launch belonging to the Station in the vicinity of Casamicciola, and noticed these large blocks of pumice. It is from these gentlemen that my information and the specimens I have examined were derived.

The presence of this large quantity of pumice gave rise to the supposition that a submarine eruption had taken place close to the northern shore of the island: and though the circumstances might certainly seem, at first sight, to favour such an assumption, yet the following facts may be cited in opposition to it.

1. No one saw the eruption.

2. Supposing it to have passed unobserved in the night, it could not have entirely ceased the next morning; and there would still have been some very considerable escape of vapour, or other eruptive materials, especially when we take into consideration the small depth of the strait at this point.

3. We should expect a larger amount of pumice than was found.

4. It is hardly compatible with the existence of a mesoseismal area within the island that an eruption should occur a short distance away, even supposing its site to be the continuation of the fissure opposite Lacco.

5. The identity, in general appearance and microscopic structure, of the floating pumice with that shaken down from the cliffs above.

6. The evident source of the floating pumice.

The following statement, given in answer to certain inquiries of mine by a fisherman of Lacco, will throw much light not only on this question, but also on that of the change of sea level, asserted by some to have taken place at the time of the earthquake. The following are his answers to my questions.

« My name is Francesco Sciazano. I am a fisherman. I had finished work on the day of the earthquake, and was sitting on the beach close to the edge of the water, looking towards the mainland. I felt a peculiar movement and then heard a noise like distant thunder or artillery, that seemed to come from Casamicciola. I remained where I was, wondering what it could be: in about a quarter of an hour, I suppose, I heard people screaming and sobbing. I got up and went to see what was the matter, when I discovered that there had been a dreadful earthquake. Although looking out to sea, I saw no light, flames, or smoke; and the stars shone out brilliantly. I can affirm that the sea was undisturbed, as my feet were almost in it. »

This man was looking in the very direction in which any such eruption must have occurred, and could hardly have failed to see evidences of it, if it had taken place. He declared there was no change in the level of the sea shore, nor any apparent retreat of the water, as was asserted by some

people ; it being a phenomenon that would have particularly attracted the attention of a fisherman on his native shore. His statement also illustrates the remarkable power exercised by seasand in neutralizing any mechanical vibrations transmitted through it: for the man, although he felt the shock, and was but a few yards from a spot which was involved in utter ruin , was conscious of but slight and comparatively insignificant movements.

The shock seems to have been transmitted to the water, for the steamer in the roads of Casamicciola, and a boat 3 miles (direction not stated) from the Punta del Imperatore , felt a blow struck under them as if they had touched the bottom.

An examination into the existence of a relationship between these earthquakes and meteorological phenomena may be said to afford no results of the smallest importance. One fact, however, that is certainly remarkable, is the more frequent occurrence of shocks at two periods of the year. If we group all the observations and draw a curve connecting the coordinates of relative frequency , we shall find that this follows somewhat the following course. Commencing in January, we have in that month a few disturbances: these increase during February , and reach a maximum in March , to diminish again during April and reach a minimum about May. From this time an increase takes place , till another maximum is reached at the end of July and beginning of August; the number rapidly diminishing again till the end of October , so that during November and December the island appears to have enjoyed absolute quiet.

The only periods in connection with natural phenomena with which, so far as I know , the above correspond , are the maxima and minima of meteoric showers: but I think it will be generally admitted that the present state of our knowledge does not justify us in inferring a relation between one series of events and the other, unless we found the earthquakes in all regions would afford a similar curve.

CHAPTER XI.

Consideration of the causes of earthquake, withs especial reference to those of Ischia.

The disturbances grouped under the head of earthquakes are at present looked upon as the result of a number of different influences exerted upon our earth. Putting aside, however, those slighter movements dependent upon the variation of barometric pressure, temperature, rainfall etc. the remaining may be said to be due to the compression, bending, and fracture of rocks by those subterranean energies, which are the offspring of the former incandescence of our planet.

These agencies are exerted no doubt in various ways, which it will be worth while to spend a moment in considering.

In the elevation of mountain chains, the gradual strain that the component rocks undergo , will reach a point at which each variety will have been brought to its limit of flexibility, and, as a consequence , rupture takes place. Such ruptures may occur at any point between the underlying plastic igneous matter and the surface, and further, such a fracture may not extend to either face of the earth's crust. This is evident when we , for instance, take the example of a bed of crystalline limestone interstratified between two beds of clay: a clinal fold would progress as long as the limits of flexibility of the limestone were not reached ; but the moment this occurs , the limestone snaps , whereas the clay would still be moulded to the new curve. Such a fracture , if on a scale in which the force was proportionally greater than the depth beneath the surface, or than the absorbing action of the transmitting medium , would be felt at the surface as an earthquake.

Now it seems that a large number of earthquakes in mountain regions are in great measure due to causes of this kind ; and in these we may

exclude direct action of any igneous matter whatever. Such a hypothesis finds considerable support in the fact of the wide distribution of such movements, with very gradual diminution from the epicentre to the periphery, showing the great depth from which they originate. There are many, no doubt, quite superficial; though the majority are derived from depths where the mechanical agencies are much more powerful and more often brought into action.

Another group is no doubt due to the fracture of the earths crust, and the immediate or simultaneous injection of an igneous magma, under great pressure, into the resulting cavity; or, in other words, that group of earthquakes that has been described as « the ineffectual attempt at the formation of a volcano ». Naturally, the depth at which the focus may be situated in these cases is very variable, so that the effects form an intermediate stage between the first and third groups.

A third class, nearly allied to the last, is represented by those vibrations that take place in the immediate vicinity of already existing volcanoes. There is little doubt that there is no distinct line of demarcation between this and the second group, for they may be said to be the result of analogous causes. A volcano has been formed, one or more paroxysms have taken place, and it then passes into a state of complete tranquillity as the result of equilibrium being re-established between the atmospheric pressure and the tension of the igneous matter; the consequence being that any magma remaining in the upper part of the volcanic chimney will gradually cool from above downwards, and so form a more or less effectual plug between the surface and the source of igneous volcanic matter. When, by a process which I shall presently describe, the tension of part of the remaining highly heated magma overcomes the superincumbent pressure and resistance, it ruptures a passage towards the surface and there bursts forth as a new volcanic eruption. The approach of this volcanic matter towards the surface does not generally take place by one single effort, but by a series of them. When the tension of the igneous magma is greater than the resistance, a fracture takes place, accompanied by the simultaneous injection of the fissure by the fluid material; and as a consequence, the tension in the fluid is reduced in proportion to the extent of the additional space afforded it. Thus, for a variable length of time, the tension, although again increasing, will be less than the resistance: but the moment the equilibrium is reached and passed another rupture occurs. The rapidity of the process will be dependent on various influences; such as, the depth from the surface, the tenacity and resistance of the superincumbent rocks, the facilities for the increase of tension in the igneous magma, the presence of old fractures and points of weakness, besides many subordinate causes. Now each restoration will be accompanied by mechanical disturbances which, should they reach the surface, we should recognize as an earthquake. Of such movements, we have examples in the earthquake of A. D. 63 preceding

the Vesuvian outburst of A. D.79 ; the shocks that disturbed Lima for years before the eruptions of some volcanoes in its neighbourhood ; as also the earthquake that disturbed Pozzuoli and the Jorullo plain of Mexico, previous to the bursting forth of Monte Nuovo and Jorullo respectively.

When by a continuous series of eruptions, a cone of some considerable height has been built up, it is often unable to support the column of lava occupying its chimney , which tends to burst its way through to the surface by a radial, plate-shaped fissure, commencing at the chimney ; and in the formation of a new, or the revival of an old, volcano, such a fissure is produced at intervals. As each rupture takes place a series of vibrations results, which constitutes those earthquakes that are generally confined to the volcano itself , or at any rate to a part of its flanks only. No better illustrations could be given than the vast number of such examples recorded of Etna and Vesuvius , foreboding the bursting forth of a series of lateral craterets , the external evidence of the true volcanic dykes. Not a year since , the former mountain gave us a remarkable illustration of this , in the earthquakes that shook Nicolosi and its neighbourhood ; premonitory symptoms of the outburst of a row of craterets close by that village.

One other and most important fact is , that the great earthquakes , almost without exception , have never the same relative distribution at the surface nor proceed from the same centre; whereas the two varieties of the volcanic group, which somewhat merge into each other , are characterised by the constant repetition of the same relative distribution, and originate in the same centre.

I think my readers will already have been struck with the remarkable resemblance between the earthquakes of Ischia and those that I have called volcanic. In fact , the evidence in favour of such a connection may be summed up as follows:

1. The shocks occur on an old volcano.

2. Former historic eruptions have been preceded by similar earthquakes.

3. The epicentre bears the same position relative to the axis of Epomeo, as do many recent parasitic craterets, as Monte Rotaro , Montagnone, and Cremate of A. D. 1302

4. The slight depth of the focal cavity.

5. The limited distribution of the mechanical disturbances.

6. The repetition of the earthquakes in the same locality.

7. The same relative distribution of injuries produced as in its predecessors, and the locality of the seismic vertical.

8. Their occurrence in a region where solfataric action is still going on.

So far, we have been arguing upon the assumption that the igneous magma has stored within itself energy, which from time to time it manifests in the production of earthquakes and eruptions: and it will be our duty at

present to inquire into its mode of action so far as is necessary for our present purpose.

Taking for granted that we have, underlying the *Campi Phlegræi* at least, a large collection of fused silicates at high temperature, let us consider how such a mass will conduct itself. Whether it is continuous, as part of the fluid envelope or interior of our earth, is beyond the subject, and affects it in no important way. This reservoir, for so we may conveniently call it, has at various points of the area above mentioned, made for itself passages through the earthcrust to the surface, and there issued in the form of lavas, scoria, pumice etc. The resulting eruptions must have occurred from narrow fissures, irregular tubes, or other sinuous passages, which in most cases are blocked at their upper extremities; but a certain quantity of the superheated magma still fills the greater part of most of them, and must there be brought into contact with water in the porous rocks constituting the walls of the passage. Now we know that water is soluble in lava, when the latter is at a high temperature and the contact of the two fluids takes place under pressure; just as carbonic acid is soluble in water under analogous conditions. The fluid magma will loose little of its original temperature, and that loss will be in proportion to the coldness of the water and the amount dissolved. Apparently, this solution takes place somewhat slowly; and as more water is dissolved, the tension of the magma will increase, owing to the tendency of the aqueous constituent to flash into the gaseous state.

The conditions are again similar to those involved in the making of seltzer water; for the larger the amount of carbonic acid dissolved, the greater the tendency of the containing bottle to burst; and should we go on forcing in more carbonic acid, the tension of the solution will overbalance the resistence of the bottle or cork, and an explosion will take place. As with the seltzer water, so with the igneous magma. For there arrives a time when one of two things must result: either the continual absorption of water will so reduce the temperature that the material solidifies as a dyke; or the tension overcomes the superincumbent resistance, and a rupture takes place, either toward the surface, or actually reaching it. In the former case we have the earthquake, in the latter the eruption.

The question arises, in the case of the earthquake, as to the mode of production of the vibrations constituting that disturbance. The actual rending asunder of the rocks must give rise to a certain amount of noise and to vibrations, comparatively feeble in proportion to what follows. Immediately after, or perhaps more properly simultaneously with, the formation of the fracture, the fluid rock is forcibly injected into the resulting cavity and is suddenly arrested by the walls. These for a moment are powerfully compressed, then rebound by their molecular elasticity, and oscillate until the state of equilibrium is restored. It is this injection and its results that give rise to the principal earthwaves that are propagated from the centre

of the disturbance in closed curves. The conditions and effects are somewhat similar to those observed in the pulse of an animal, or to that peculiar vibration produced by suddenly shutting a tap from which water is pouring under considerable pressure. The most vivid illustration may be obtained by closing the outlet of a leather fireman's hose, which is empty and collapsed so that no real cavity exists; if we now connect it with the steam pump and place our hand on it, the sudden filling and the shock produced by the arrest of injection by the walls of the tube, yield a sensation remarkably like that arising from the type of earthquake we are now discussing. Even the oscillations of the wall of the tube are evident to the eye.

It seems very doubtful whether any actual formation of steam or gaseous water takes place or not. If such really did occur, it would be in the form of bubbles scattered throughout the igneous magma. So far, geology leads us to adopt a negative conclusion, from the number of ancient dykes that have been exposed by denudation, and which comparatively rarely show vesicular structure. For in the cases where such does occur, the dykes in all probability communicated with the atmosphere through a volcanic vent. Even in the superficial dykes of Monte Somma and the Val di Bove, it is only near the surface, or their exit, that they assume a vesicular structure.

At any rate, we have not the slightest evidence, in past or present geological times, of steam, as steam pure and simple, being the motive agent of earthquakes, although all recognise the important part it plays in eruptions, by its formation and escape. For by its agency a vitreous or semicrystalline magma may assume, on the one hand, the dense compact crystalline characters of a lava, or, on the other, the light cellular characters of a spongy pumice, according as the mother magma contains much or little water in solution.

So far, we see that the motive power of earthquakes is the heat stored up in the igneous matter, which exerts its power through the agency of water; and that this display of energy is most likely to take place with greatest violence in ramifications of the volcanic magma contained within the earths crust. Thus, we find an easy explanation of the remarkable fact that one volcano may burst forth without affecting its neighbour , or that an earthquake may, and often does, produce no observable change in active volcanoes close at hand. The effect of rainfall, variation of barometric pressure, etc., on the prevalence of earthquakes becomes quite obvious, if we remember that, when tension and resistance are nearly balanced, it requires but a « last straw » to determine the excess of the former over the latter, and to induce its accompanying effects. The fact that on the day on which the earthquake occurred in Ischia in 1828, Vesuvius became very active, seems to show that the same influence was the determining cause of both disturbances. In 1867 no such relationship manifested itself ; for Vesuvius did not change. Again , in 1881, not the slightest sympathy was shown by Vesuvius with the Ischian earthquake. It was two days after the earthquake of July 28th 1883, that Vesuvius exibited any sympathy with the Ischian seismic disturbances. And even then, it is

doubtful whether its increased activity was more than a simple coincidence, for the augmentation did not occur till July 30th, or nearly 36 hours later. The volcano then passed into a somewhat long and accelerated eruptive stage; but such only as has been of very common occurrence, especially since 1872.

The line of argument that we have been following has led up to the conclusion, that we have an aquiferous igneous magma spasmodically rupturing its way to the surface. This conclusion , of its progress upwards is confronted , however , by the fact that we found the mean focal depth of the earthquake of 1883, to be a few meters lower than that of the earthquake of 1881. We must remember, however, that our calculations are based on only approximate data, some of which are, in all probability, far from the truth, and that there is no reason whatever why an error of 25 or even 50 meters, may not have occurred between the mean calculated, and true depth. Now , if this error lies in diminishing the depth of the focus of 1881, or increasing that of 1883, the difficulty is immediately eliminated.

There is another way in which the disturbances may fail to reach the surface. Let us suppose that in 1881 a narrow fissure was formed, and injected by aqueous magma, the contact of which with its cold walls may have resulted in such a reduction of temperature of the lava, as to solidify it and so plug the new rent. As a consequence, the next time a rupture took place, it might be by the side, or in the vicinity, of the old fracture, and might not extend so far in an upward direction.

So far as my own individual opinion goes , I am inclined to attribute the above mentioned anomaly , rather to imperfection in the calculations than to any other cause. At any rate, it is impossible to believe that the rent is extending downwards.

When discussing the various destructive characters of Ischian earthquakes a few days after that of 1881 , I pointed out in Nature (1) that we may expect repetitions of these terrible catastrophes. And again in the same periodical, a few days after the shock of 1883, I repeated much the same words, but with greater confidence. I quote them here: «We must expect other shocks more violent in character , and that as one follows the other , the interval of tranquillity will be less, until the final eruption bursts forth. What time such an occurrence may be expected, it is only possible to judge by the force, character, and frequency of future events. »

Of course, these words must not be taken too literally ; for , from the number of disturbing influences acting upon the magma , the varying conditions that are brought to bear upon the active agents at work , and the impossibility of gleaning more than the merest hint of what is going on beneath the surface, the real sequence of events can not be foreseen with

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(1) March 24th 1881. Vol. XXIII
Letter, dated July 30th 1883, in Nature. Aug. 9th 1883 vol. XXIII.

sufficient certainty. Yet, if from a properly organised series of investigations, of which I shall treat in the next chapter, we find that the focal cavity is approaching the surface in a definite direction, the question arises whether we should not be justified in adopting some preventive measures. Supposing that we have determined the exact limits of the focal cavity, have ascertained that it really is approaching the surface and is not far distant from it; what measures suggest themselves as most suitable, not to prevent (for that is impossible) but to render as harmless as possible, the inevitable outburst? If I may crave the reader's patience, I will venture to make certain propositions which may appear fool-hardy, giving but dubious prospect of success.

I would, as a first measure, evacuate the whole of the region N. of a line drawn from Citara to Porto d'Ischia, so that, in case of necessity, the inhabitants of the rest of the island would have time to escape. That they would so escape is hardly likely, if we may judge from the experience of former outbursts. This evacuation I would cause to be carried out in the autumn, when all the crops had been gathered in. Then an artesian boring of large diameter should be commenced exactly over the focal cavity, which even at the present day is not so deep as some of the wells of that description lately made.

I should expect that the limited size of the bore, and the premature escape given to the igneous matter would tend to render its eruptive violence less than if left to follow its natural course itself; but besides all that, we could determine the eruption at the moment when it would produce the least damage. Perhaps many of my readers may pass by these suggestions with a smile of incredulity and derision; but I am sure that if they will carefully weigh the advantages on both sides, they will give their verdict in favour of human intervention. Even supposing that, from some unforeseen circumstances, the experiment failed, yet the cores brought up in the operation of drilling would afford a most important addition to our knowledge of the geological structure of this interesting region, and we should, at the same time, add another source of fresh or mineral water for the use of the inhabitants. At any rate, if we have gained any knowledge of terrestrial physics, it surely becomes our duty to turn it to a practical use and thus to benefit our fellow men.

CHAPTER XII.

Means suggested for employment in the investigation of the Ischian terrestrial phenomena.

The fact that a study of the present and future seismological phenomena of the island has such a claim upon our attention, both from a scientific and a humanitarian point of view, has induced me to turn my thoughts for some time to this important subject.

Our study of past phenomena affords us sufficient information to direct our steps on a line of investigation for the future which may yield much more valuable results than those derived from the rough methods so far adopted. We have learned almost without doubt that volcanic matter is rupturing its way to the surface through a plate-shaped fissure; and we should adopt whatever means we have in our power to follow its progress, and if possible give warning of the final outburst. These results, too, having been obtained from observations of the destructive effects of terrestrial movements upon buildings, in themselves very far from homogeneous, are necessarily but mere approximations to the truth.

The small area affected by the earthquake, the easy accessibility of the island, the natural facilities for the foundation of a seismological station, with its appendages, and the vicinity of a large town, one of the centres of European traffic, render Ischia peculiarly advantageous as a locality for the foundation of such an institution, in which original geological and seismological researches might be carried on. By such means our knowledge of the relation between earthquakes and their cause might be rendered far clearer and more extensive. We should not only ascertain whether any premonitory signs of an earthquake really exist, and, if so, what is their exact meaning; but we could, at the same time, note the slow or rapid progress of the igneous matter towards the surface, and so be enabled to

warn the unfortunate inhabitants of their peril in sufficient time to insure their escape. From my acquaintance with the circumstances under which such a station should be constructed, and also with its requirements, I venture to make the following suggestions. First, there should be a central observatory built, earthquake-proof, so far as concerns the walls and roof, with a residence for the seismologist in charge. This building should be provided with a complete set of instruments of various kinds, both seismological and meteorological.

Then I would propose to scatter around the epicentre two circles of subordinate stations, four or six being in each circle. For these secondary stations some of the cellars cut out of the solid tufa, of which there are thousands in the island, might be secured, and these would be the very best places imaginable for the purpose. Each of these should be provided with instruments continuously registering azimuth, angle of emergence, amplitude of earth wave, duration of shock etc. In addition to these a small station might be erected over the seismic vertical, containing only instruments for measuring vertical movements. All these subordinate stations should have self-registering instruments, so that only periodical visits would be necessary. All the stations of the outer circle should be situated on the same radius from the epicentre, so that the velocity of transmission might be thus obtained in different directions. At the central observatory, microseismic instruments might be employed.

Observations on the quantity and outflow of the principal thermo-mineral waters, and on the temperature, character, and quantity of the vapour from the fumaroles, should be made, and the result registered.

If each of these instruments were also self registering, the whole of the observations might be under the care of a single individual.

An automatic tide register would complete the equipment.

Such an organization would be costly only so far as concerns the instruments, and the maintenance of a competent observer. The expense of the building would be small, and the rental of the tufa caves would be merely nominal, for a large number of them are not even made use of.

That such an institution is needed, there is little doubt; and were it made international, as is the Zoological Station of Naples, its uses might be widely extended, in the investigation of the higher branches of geology and terrestrial physics, the latter of which is still in a decidedly backward state.

APPENDIX.

— A —

Suggestions for the reconstruction of Casamicciola and other towns (1).

Immediately after the destruction of Casamicciola and Lacco Ameno a number of suggestions were put forward for the reconstruction of the houses in various materials and designs. Let us consider the mechanism by which a building is destroyed by an earthquake.

In those movements which constitute a destructive earthquake we have a focus varying in depth from the surface ; this focus is probably in most cases in the form of a linear fracture or fault, or a fissure that may vary in position, size, and direction. In the present case, all the evidence points to a radial fissure running from a few degrees W. of N. to a few degrees E. of. S., passing just W. of Casamenella , and which, originating in the old chimney of Epomeo, is tearing its way to the surface. The rending asunder and immediate injection of such a cavity by volcanic matter, possessing an enormous tension, give rise to the vibrations of the earthquake. These pass out from the focus or fissure in waves of the form of concentric shells; and therefore arrive at the surface at various angles , where they produce effects entirely dependent on the situation of the building relative to the focal centre. In consequence of this fact we must construct our houses, so that they resist the kind of movement to which they may be subjected. Such a system of course can only hold good for a region that possesses a permanent seismic centre such as Ischia.

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(1) Compiled from articles written by the author and published in « L'Italie » of Sept-2nd 1883, « Il Piccolo » Sept. 26th 1883, « L'Italie » Sept. 15th 1883 and « Notices on the earthquakes of Ischia of 1.81 and 1883 » Naples 1885 p. 47 and 52.

Any point on the earth's surface describes, during each wave, an ellipse, whose plane is at right angles to the surface, and parallel to a radial line drawn from the focus to that point. In other words, any point on the earth's surface begins by moving upwards , then forwards , downwards , backwards and then again upwards, and so on over and over again as long as the disturbance lasts. When near the centre of disturbance , the ellipse has its longer axis perpendicular to the surface, so that the vertical movement is great and the lateral one small. We then have *subsultory* shock. At the epicentre the movement would be represented by a line; and where the emergence was near 45° the ellipse would be replaced by a circle; beyond this point the major axis of the ellipse would be horizontal, so that lateral motion would predominate over the vertical, until at infinity the movement would take place in a right line parallel to the surface. Where the ellipse has its major axis horizontal, *undulatory* shock would be experienced.

The destruction produced in buildings is due to their incapacity to follow these movements. Their great weight , as ordinarily built in Ischia , gives them enormous inertia , so that it is some time before the earth's movements can be communicated to them, and, as a result, when the foundation is carried forward by the earth, the upper part lags behind. When the earth returns, the upper part has commenced to move forwards, but the foundation is going backwards , so that the walls are fissured and broken by the strain between their free, and their fixed portions, or foundations , often even crumbling to pieces , since their elasticity and the cohesion of their constituent parts is almost nil compared with their weight.

We see therefore that for buildings to withstand principally undulatory movements we may adopt two methods: in the first place we may make them stronger so that they may be able to resist such movements ; or on the other hand we may isolate them in some way from the ground.

The first principle we may carry out in a variety of ways. To increase the cohesion of masonry walls iron tie-bars are often inserted. Anyone who has examined the houses at Casamicciola will see that not only were they useless, but positively injurious as is well exemplified in the Villa de Majo (Photo. X.). and St. Rosario (Photo. XIII.). It would seem that the energy that in an ordinary building would be expended in producing a great number of very small fractures between the separate stones , here is exerted on the whole mass held together by each tie-bar; which mass, from its weight and wider range of movement, completely ruins any building. This result simply arises from arranging the tie-bars horizontally so as to form a series of rings as , for example , in the Villa di Majo ; the building being thus broken up into a number of tiers which shift one upon another.

If resort be had to iron tie bars, they should form a complete framework to all the walls and floors, which, from their quadrangular form , require

breaking up into triangles by diagonal bars from one corner to the other. There are, however, two great objections to the mixing of iron bars and masonry :

1st. The diagonal bars from the lower corner of a wall on one side , to the upper one opposite , would require a special arrangement of doors and windows , so as not to interfere with them ; a difficulty which all architects will but too fully realize.

2nd. The continual strain produced by change of temperature in causing contraction and expansion of the iron bars running in different directions, although slow, would be a sure agent in the gradual disintegration of the masonry.

It is no doubt possible that a moderately secure house might be made by combining masonry with a net-work of tie bars or girders in the walls and floors, so that they could resist both subsultory and undulatory shocks.

Another principle that we may adopt with greater success is to employ materials with the minimum of inertia and the maximum of cohesion and elasticity. Such materials we have in iron and wood.

Considering the merits of iron as a material for construction, we find that it stands first as regards its lightness combined with great tenacity and elasticity, but that it presents certain inconveniences. It is costly; it requires careful and continual attention, or it rapidly oxidises near the foundations, especially in volcanic districts; and lastly, it is insufferably hot in summer and cold in winter. Nevertheless, it may be largely employed, if carefully attended to and well tarred or painted ; whilst the objection to it on the score of its great capacity as a heat conductor might be easily overcome by using double layers for the walls and roof, the interspace being packed with pumice stone or sawdust,

Passing now to consider wood , we find it has a great number of advantages; namely, strength, elasticity, and comparatively low cost. But two very important objections may be urged against it: its liability to fire and to the various forms of decay. The first we might overcome either by a proper supply of water, which, however, is almost impossible to obtain in Ischia; or by rendering the wood uninflammable. The use of some chemical agent of the type of Zinc chloride would not only procure the desired uninflammability, but would also protect the wood from decay, or, in other words, from the inroads of insects and cryptogamic plants: to which latter end free ventilation would still further conduce.

Altogether I think that in the locality under consideration it will be found convenient to construct composite houses of iron and wood, the latter being used for the lining. For the lower floors a solid framewoork of iron or wood, with a judicious introduction of hollow tiles and good cement (the former of which are manufactured on the spot) would be justifiable. The floors, and in some rooms even the walls, might be covered by the thin French tiles. In fact, if the houses are designed in a proper manner, they

may be made more hygienic, more commodious, and pleasanter than those of masonry.

Besides the mode of construction, and the materials that enter into the building of houses, etc. we must consider their form and position. It is an old and well established fact in mechanics, that a house with its longer axis placed radially to the epicentre, resists far more than when tangentially situated. The following empirical proportions will I think give sufficient security, provided the cohesion of the building, as a whole, is sufficient. The height of the house should never exceed three quarters its length, and its breadth should always be more than half its length. It would probably be convenient to build large edifices in a pyramidal, or more properly step like form, so that each floor would cover a diminished area.

We have seen that the main cause of the destruction in houses is due to the earth's movements being communicated to the upper parts too late, and after the foundations have commenced to move. This defect might easily be overcome by using four strong tie-bars or chains which, being in direct communication with the iron framework, would extend from each of the top corners of the building downwards and outwards and be attached to piles or masonry piers in the ground. The angle that these ties form with the ground should be 45° or less. They would act as the cords of a tent, converting the house into a hollow truncated pyramid, and communicate the earth movement to the top and bottom of the building simultaneously.

So far we have studied the principle of fixing the edifice firmly to the earth, and, at the same time rendering it capable of resisting the severe strains to which an earthquake may subject it. There now remain to be considered the various methods of isolating the building from the earth. The old well known plan of making caves beneath the foundations is no doubt of very great service not only in the case of subsultory, but also in that of undulatory movements: and where the compact Epomeo tufa comes to the surface. Then we have the system of supporting the building on balls, or similar mechanical arrangements, such as those adopted by Messrs Stevenson and Milne in Japan. The great expense, difficulty attending this mode of construction, and (I think I am right in adding) its comparative uncertainty of action, combined with the fact that it affords protection from undulatory movements only, exclude the possibility of its employment in the island of Ischia. Of course it might be possible to introduce a kind of spiral spring mattrass above the balls to absorb vertical motion; but with such arrangements a dwelling house would represent a great and costly seismograph. There is yet one other measure that we may adopt, which holds an intermediate place between the two last mentioned plans; and, as I believe it is original, I will mention it. The building should have its foundations replaced by a strong cohesive platform resting on a thick stratum of loose sand or pumice stone, both of which are abundant close at hand. This should fill an excavation of some considerable depth and of an area greater than that

covered by the building. The principle involved is of course the using up of the earthquake energy in friction and crushing of each individual particle; and as regards the use of the pumice, the interception of numberless air vesicles.

Altogether, individually, I by far prefer the principle of fixing the house rigidly to the ground and communicating the earths movement to the whole of it simultaneously, whilst securing that the floors and ceiling be of great tenacity combined with lightness.

It now remains to consider what sites are suitable for the reconstruction of Casamicciola and Lacco.

There is little doubt left in the minds of most people as to the volcanic nature of the earthquakes in Ischia. The question arises as to what character we should expect future terrestrial phenomena in the island to assume. All the evidence points to the existence of a fissure whose upper extremity is not far from the surface ; a fissure filled with lava holding a considerable quantity of water at its own temperature, ready to flash into steam the moment the superincumbent pressure is removed. From these conditions one of two results may follow.

1stly. Should the expansive tension of the lava increase, from the further absorption of water, without its temperature being reduced below consolidation point, a time will arrive when the said tension will be sufficient to overcome all further obstacles, and an eruption will take place. Such an outburst will probably occur at some period of general seismic activity, which, increasing the pressure at the great centre, or centres, of volcanic action, will be the determining cause for the eruption at a weak point.

2ndly. Should the loss of heat of the magma reach the consolidation point, from such causes as (a) conduction by the neighbouring rocks, (b) absorption by subterranean currents of water, which thus become thermal (c) absorption of water by the igneous magma ; then the fissure may be plugged, and more or less completely sealed, by the congealed lava filling it, so that any further eruptive tendency will have to find a new aperture.

The science of seismology, still in its infancy, cannot yet tell us which of these alternatives will occur. But arguing from probabilities, we have the following reasons for expecting as the final result of the processes in operation, that a volcanic outburst will take place. Firstly, the history of former catrastrophes in the island; secondly, the close proximity of lava to the surface ; thirdly, the decreasing period of tranquillity between one earthquake and another, with the greatly increased violence of the latest; fourthly, the almost continual repetition of small shocks since the last great one.

Even supposing we had not this evidence in favour of the first of the two alternatives, it would be our duty to consider what terrible results might happen, were we not to prepare for the worst.

As I have already pointed out, the plane of the fissure is parallel to, and beneath, a line drawn from Fontana through Casamonte, to the eastern part of Lacco. It is almost certain that the eruption would take place somewhere along this line ; but the mass of Epomeo would offer such resistance to an outburst through it, that a shorter path would probably be chosen, which would terminate somewhere between Casamonte and the road to Frasso.

An opening at this point would hold almost the same position relatively to the main axis of the mountain, as do its predecessors M^t. Rotaro, Montagnone, Cremate, Molara, and Fondo di Casapolita.

We will suppose that the eruptive mouth has formed; what amount of ground will the ejectamenta cover, and of what size will the cone be ? An answer to such a question must necessarily be of the most imaginary kind, and therefore we should not be justified in attempting to hazard more than a conjecture. Nevertheless, taking into consideration the size of former crater cones in the island, we should be probably safe in estimating the diameter of the future cone at a kilometer and a half; that is to say, an area of three quarters of a kilometer on each side of the line of fissure would be covered. If lava should flow out, as from Rotaro or Cremate, it would probably reach the sea by the valley that divides Lacco from the district of the Annunciata.

I should propose, therefore, that no houses should be permitted in this area. I mean by this, no buildings that would be permanently occupied by human beings. Cantines and agricultural stores of course are not included.

Outside this area, the inhabitants would no doubt have sufficient warning and time to remove the most valuable of their property, and especially to save themselves.

So far, we have only studied the precautions necessary against an eruption ; but there is good reason to believe that other earthquakes will precede such a termination, and they are natural phenomena to be feared as much as, if not more than, the appearance of a parasitic volcano.

One remarkable fact, illustrated in the earthquake of July 1883, is that houses built on the sea-sand suffered very much less than neighbouring ones built on alluvial, and therefore loose incoherent, tufa. And these latter, again, have suffered much less than those built on the comparatively hard tufa rock of the island. The maximum damage, proportionally to the distance, occurred on, or in the neighbourhood of, the masses of highly elastic trachyte.

One other source of excessive destruction was the position many buildings occupied near the edge of a cliff. When a mass of earth of this form is set in vibration, especially if composed of incoherent materials, a landslip will be produced; or a series of fissures only, more or less extensive, will be developed parallel to the free border of the scarp. These, although perhaps not very apparent, are highly destructive to any building whose foundation is in that locality. Two good illustrations in the last earthquake

are furnished by the districts of La Tresta and Olivieri, which lie along the the western bank of the vallone Ombrasco.

From these facts, we learn that buildings should be placed on nearly, if not quite, level ground, at a considerable distance from any scarp or cliff-edge.

It appears at first sight, that it would be preferable to build all the houses on the sea shore, where they would have a foundation of sand. This would no doubt be the best protection against injuries dependent upon earthquake vibrations; but there is another evil we must not lose sight of.

Earthquakes, in volcanic and other regions, on the sea-bord, especially immediately preceding an eruption, have often produced such violent changes of level, that the sea has receded, and then rushed inland, drowning the inhabitants in large numbers. Of such phenomena we have many examples, amongst which I may mention the terrible catastrophes on the western coast of south America, that of Lisbon, not to speak of the recent one in Java, where 10,000? people in one town owed their death to such a wave. Pozzuoli in 1538, and Vesuvius in 1861 presented similar, though feebler examples of the same kind. In my opinion, we need hardly expect, in Ischia, a disturbance greater than that realized in the two latter examples, as the seismodynamicity of this island seems to be comparatively very feeble; nevertheless we should, I think, avoid localities at a very low level.

We must therefore choose plains of the loose alluvial tufa, which we have in the following localities: near the Villa Maresca and the fumaroles of Monte Tabor (already partly occupied by the new huts), near the Masseria della Torre, on the right of the road up to the Parrochia, the district between Mezzavia, Mt. Marecocco, extending to St. Aniello, and Spadara (1).

The area avoided for the construction of houses might be very well utilized for the cultivation of vines and for other agricultural purposes, so that no great pecuniary loss would result.

In this short communication, I have tried to sketch in outline the precautions necessary to be taken to prevent further catastrophes. Whatever opinion scientists may hold as to the cause of former disasters, they can hardly disagree with the suggestions I have put forward; as the preventive measures will be much the same, whatever may be the origin of these terrible earthquakes.

I have endeavoured to collect all the facts, though they are but few, that are at our disposal; to weigh them carefully, and to draw conclusions from them, without a determined partizanship for any particular theory, or

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(1) The sites for the new towns proposed by the author were finally adopted by the government commission. (Relazione della commissione per le prescrizioni edilizie dell'Isola d'Ischia, istituita dal ministro dei lavori pubblici (Genala) dopo il terremoto del Luglio 1881, pag. 37.)

an excessive belief in the teachings of the science of seismology, as yet in its infancy. May this work be of some practical utility.

With these remarks I bring this memoir to a close and while thoroughly conscious (as indeed I am) of its deficiencies, yet I trust that my errors may be condoned, and that my work, imperfect though it be, may be found to have cleared away somewhat of the obscurity that envelopes one of the most terrible manifestations of Nature's forces.

— B —

Two unpublished letters of Covelli relating to the earthquake of 1823

These two letters, addressed by N. Covelli to T. Monticelli, whilst the former was studying the earthquake of 1828, have never been published. They fell into the hands of Sig. Vincenzo Flauti, the perpetual secretary of the *Accad. delle Scienze* of Naples, by whom they were presented to Alexis Perrey, who prefaces them by « Dijon le 7 Novembre 1853. » After Perrey's death his library was bought by the Naples section of the Alpine Club, and with the numerous additions that have been made to it constitutes the most complete library of Vulcanology and Seismology in existence: containing over 6500 volumes and pamphlets and above 200 manuscripts.

« Lacco February 3rd. 1828.

Gentilissimo Cavaliere

I write in haste to say that yesterday at 10,30 a. m. a horrible earthquake was felt, such as has never occurred in the island in our times. Casamicciola is destroyed. Yesterday there were excavated from the ruins thirty corpses, and the wounds of more than fifty persons were dressed. The excavations continue, because there are many other unhappy beings under the ruins. Lacco has not much suffered, because only a few houses have been fissured. The inner walls of the Casa Manzo are also fissured (1).

(1) Casa Nesbitt.

The earthquake announced itself by two strong shocks which everyone noticed to come from the mountain. The focus was at La Rita, the place where the mineral water is; in Ischia it was hardly perceived, and at Forio the earthquake was sensibly much less than at Lacco. Only one country house, that of Signor Matese (1) towards Fango, fell down. We remain so dismayed that we have not had strength to drag ourselves up to the Rita to see what changes have taken place there, or to see if the Stufe di S. Lorenzo have given any signs of alteration.

In another letter I will give you a detailed description of the terrible catastrophe, so that in reading it before the Academy, you may excite the pity of the Minister of the Royal household who is a noble-hearted man; as well as of the sovereign, ever ready to help the unfortunate.

In the meantime,

Your most obedient servant
N. Covelli »

« Lacco February 7th. 1828

Gentilissimo Sig. Cavaliere

The island is quite quiet after the great catastrophe. Everybody is running to Casamicciola to see the ruins. A hundred sappers, sent by his Highness, are occupied in excavating the bodies, and demolishing what the earthquake has still left standing in the locality. Yesterday a person was found unhurt after a fast of four days: immediately on coming out in the air she fainted, but after a few minutes recovered her senses and asked for something drink. The beats of her pulse were not more than 25 per minute, but the pulse was not feverish. On the same site were found three bodies, brothers of the girl, and the body of the mother, who was pregnant. Without the help of the government, which is, and was, always ready, there would have been new victims, because notwithstanding that many houses still standing threatened to tumble down from one minute to the other, the inhabitants exposed themselves in seeking for relations, looking after their goods, as also to hunt amongst the heaps of ruins where still lay buried many persons.

I have been twice to Casamicciola to see the spring of the Rita, and the openings of the ground, which they said were enormous. The Rita water has suffered no alteration whatever; and the openings in the ground are

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(1) Probably Maltese.

nothing more than fissures of less than an inch, which occur in raised ground sustained by banks; but where the ground does not form banks, as the middle of the *Piazza* of Casamicciola and in the vine gardens, there, one finds no fissures. The vapour baths of S. Lorenzo and the waters of Monte della Misericordia, as also Spenna Pollastri, Gurgitello, Capone, Occhio, Ferrata, Tamburo and Cotto do not show the slightest change. After these observations, I felt more reassured , as it is probable that the cause of these strong shocks is very deep, and it will be some time before a fire-vomiting mouth opens towards this eastern flank of Epomeo. Notwithstanding this reassurance afforded by science we are not yet perfectly tranquil. We sleep on the ground floor near the door of the garden, which we leave ajar, and we also work and eat there, but at the slightest shock, the cry of some boy in the street, we change colour and jump outside, in such a way that we end by laughing, and we again merrily commence work.

Give my greetings to Giovannino with Medea and Cangiano, whilst with the usual respect I remain,

Your most obedient servant
N. Covelli.

P. S. I have perused the chemical portion of the work of Fabroni; in fact I have an extract to send to Guarini for publication in the «Esculapio.» When you read the article you will see that our Andria was infinitely superior to Fabroni, who by this work wishes to lose that reputation which he acquired in a manner I do not understand. »

EXPLANATION OF PLATES

PHOTOGRAPH I. Panorama of Casamicciola taken from near Frasso after the earthquake of March 4th 1881. (1)

PHOTOGRAPH II. Blank gateway in the Via Roma, Casamicciola. The photograph shows two columns broken off; one has fallen, whilst the other has rotated on its base (2).

PHOTOGRAPH III. Entrance to Menella. Looking due E. with the parish church of Casamicciola in the background. Taken just after the earthquake of 1881.

PHOTOGRAPH IV. The two portions of the Villa Balsamo. Looking towards N.W. with Monte Vico in the distance.1883. (3)

PHOTOGRAPH V. Ruins of the Monte della Misericordia. Looking nearly due W. The Piccola and Grande Sentinella on the hill to the right. The entrance to the Piazza di Majo to the left. 1883. (4)

PHOTOGRAPH VI. Church of the Madonna dell'Assunta, Piazza dei Bagni, Casamicciola. Looking nearly due W. 1883.

PHOTOGRAPH VII. Chimney of the Stabilimento Belliazzi , Casamicciola. Looking nearly N. The ruins of the Monte della Misericordia in the background. 1883.

PHOTOGRAPH VIII. Blank gateway in the Via Roma , Casamicciola , the same as seen in Photo. II., with which it should be compared. This view includes a little more of the road. 1883.

PHOTOGRAPH IX. The Hotel Piccola Sentinella , Casamicciola. Looking nearly N. W. 1883. The salon was beneath the ruins seen at the right extremity of the building. 1883.

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(1) All these photographs were taken soon after the catastrophe. Many of those for sale show more the result of the dynamite used to bring down the tottering walls than the effect of the earthquake, being taken some days or weeks after the event.

(2) The white spots on the wall are sunbeams traversing the trees opposite.

(3) For *dis* read *phot.*

(4) For *dis* read *phot.*

PHOTOGRAPH X. Villa di Majo; looking nearly due E. 1883. Observe the large number of iron tie-bars inserted after the earthquake of 1881. Much of the building has fallen, and as the emergence was high, all the floors and ceilings were destroyed, resulting in the loss of many lives.

PHOTOGRAPH XI. Piazzo di Majo and district just N. of it; looking about W. S. W. Searching for wounded and dead. 1883.

PHOTOGRAPH XII. Casamenella; looking S. E. 1883. Exhibits the degree of destruction in the mesoseismal area.

PHOTOGRAPH XIII. The church of St. Rosario at Lacco; looking nearly due N. 1883. It was undergoing repairs for damage done in 1881.

PHOTOGRAPH XIV. Main street of Upper and E. Lacco; looking from near St. Rosario eastwards. The Grand Sentinella is seen on the hill in the distance. 1883.

PHOTOGRAPH XV. Northern end of the Grand Sentinella; looking about S. E. The interior had already been cleared out in search of dead when the photograph was taken. 1883.

PHOTOGRAPH XVI. The church of S. Sebastiano, Forio; looking nearly due E. The ruins of the steeple are hardly visible from the deep shadow. On my returning to the locality to obtain a better photograph the roadway had been cleared. 1883.

PHOTOGRAPH XVII. Side entrance to the Villa Pezzillo; looking towards 30° W. of N.

PHOTOGRAPH XVIII. Gate of the Villa Gastaldi some distance N. of the Villa Calitto (Pezzillo); looking nearly due W. The ruins of the Villa are seen through the gate. 1883. This photograph is intended to show the rotation of the tops of each gate pillar.

PHOTOGRAPH XIX. Panorama of Casamicciola from near Frasso, looking nearly N. After the earthquake of July 28th. 1883.

PHOTOGRAPH XX. View of the two landslips above Fango from Mezzavia, looking about S. S. E. Panella is seen to the left. 1883.

PLATE I. FIGURE 1. Gateway of garden of the Villa Maresca showing displaced pillar stone and falling of one half of the gate. 1881.

FIGURE 2. Blank gateway in the Via Roma (Photo. II)
A. Front elevation.
B. Side elevation.
C. Details of pillar.
D. Plan of rotation of broken pillar. 1881.

FIGURE 3. Direction post, at the junction of the Via Roma and Via Sassola, broken at the level of the side walls. 1881.

FIGURE 5. Staircase at the back of the old Municipio. 1881.

FIGURE 6. Diagram of the fractures in the Masseria della Torre. 1881.

FIGURE 7. Diagram of injuries in house of the Strada Castanito. 1881.

FIGURE 8. Front elevation and plan of entrance to the Masseria Chiappa.
a. Dropped key stone
b. Fractures. 1881.

FIGURE 10. Roofs at Fontana.
A. As seen from below.
B. Diagrammatic vertical section. 1881.

FIGURE 12. Peculiar fracture and bending of a wall. 1883.

PLATE II. FIGURE 4. Side elevation of staircase and fallen flower vase at the Piccola Sentinella. 1881.

FIGURE 9. Chimney of the Masseria Spadara.
A. Under side of cap showing white marks where it rested on the pilasters before and after the earthquake.
B. Side view. 1881.

FIGURE 11. Fallen flower vases and wall of road near the Villa Sauvé.
A. Side elevation.
B. Plan.
C. Details of flower vase. 1883.

FIGURE 13. Chimney at Monterone showing displacement of cap and removal of two covers from the smoke apertures. 1883.

FIGURE 14. Plan, to scale, of S. Maria di Loretto at Forio. The fissures are as seen in roof when looked at from below. The cross-hatched square at the right lower corner was the situation of the tower containing the bells which fell to the E.and crushed in the roof.1883.

FIGURE 15. Displaced picture.
A. Front elevation before earthquake.
B. Same after earthquake.
C. Side elevation before earthquake.

PLATE III. Map of the island of Ischia, showing azimuths, isoseismal curves, and probable plan of the fissure of the earthquake of March 4th. 1881. Also the thermo-mineral springs and fumaroles of the island. Scale 1:25,000. The position of the section in PLATE VI. is indicated by the thick black line.

PLATE IV. Map of the island of Ischia showing azimuths, isoseismal curves, and probable plan of the fissure of the earthquake of July 28th. 1883. Scale 1:25,000. Also the three principal landslips. In both PLATES III and IV, the numbers correspond to those of each observation in the text.

PLATE V. FIGURE 1. Diagram of emergence of wave-paths of the earthquake of 1881.

FIGURE 2. Diagram of emergence of wave-paths of the earthquake of 1885.

The vertical thick black lines, from the top of which the inclined ones start, indicate the height above mean sea level of each locality of observation.

In both figures the numbers correspond to those of the observations in the text and in the two corresponding maps in Plates III and IV.

PLATE VI. Diagrammatic section of the island of Ischia through the plane of fracture (See Plate III). True scale of 1:25,000, both vertical and horizontal. The mean limits only of the focal cavity are here indicated, the real limits should therefore be greater for each earthquake.

Fig. 1

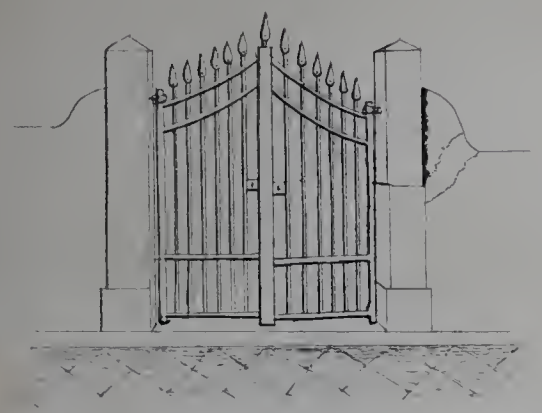
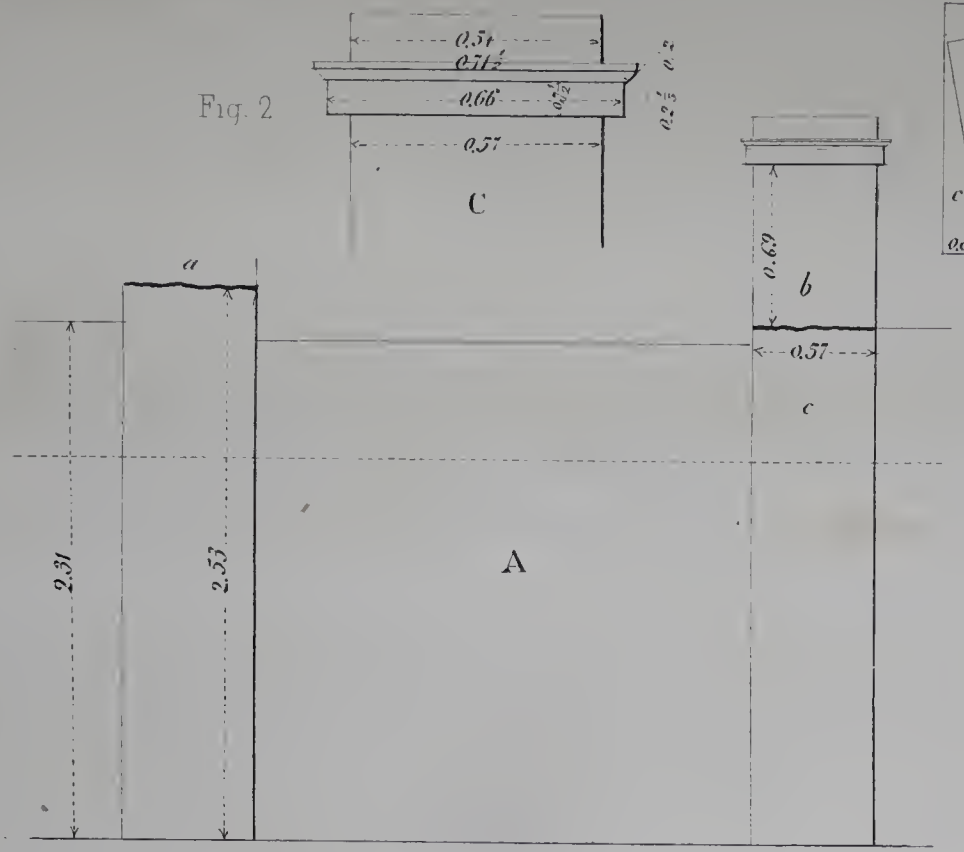
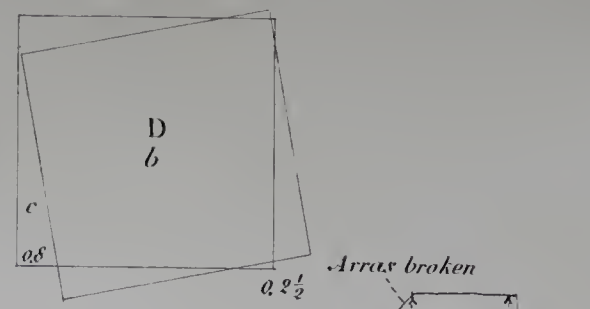


Fig. 2





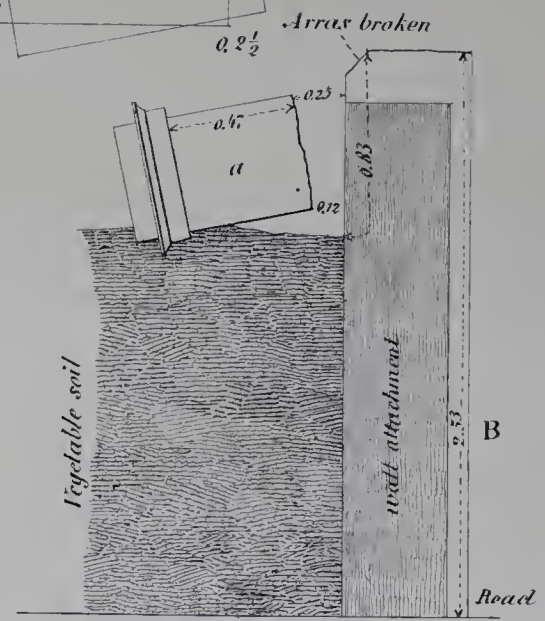


Fig. 5

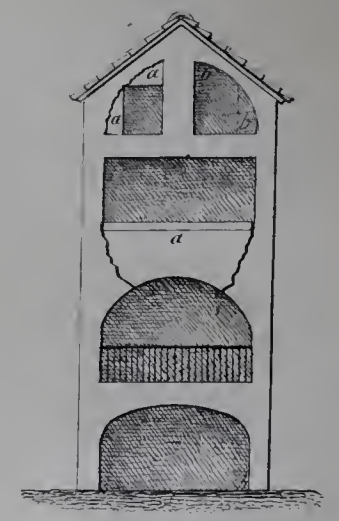


Fig 3

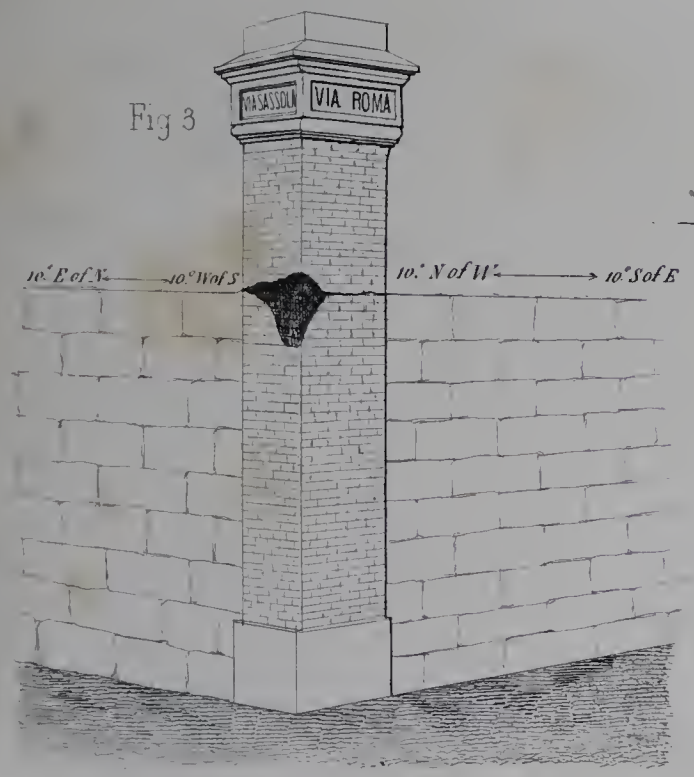


Fig. 6

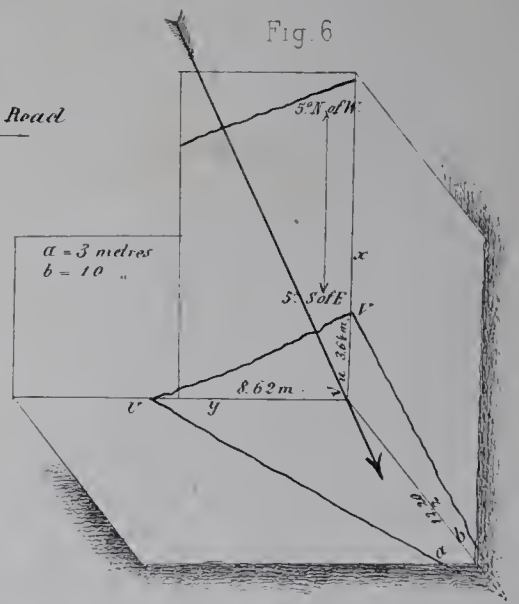


Fig. 7

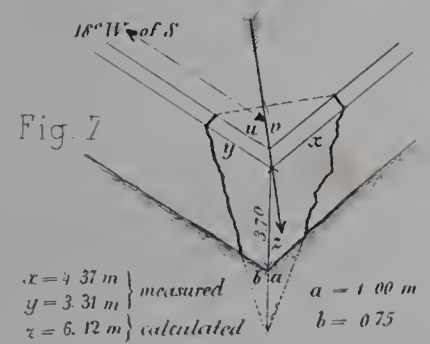


Fig. 10

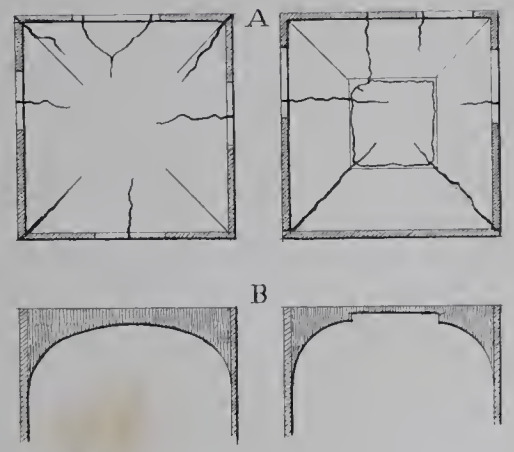
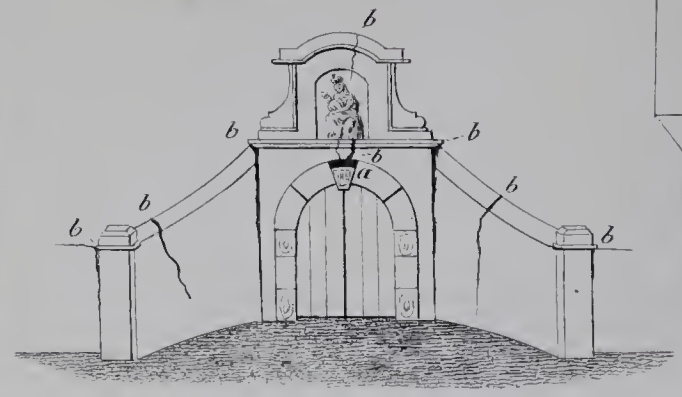
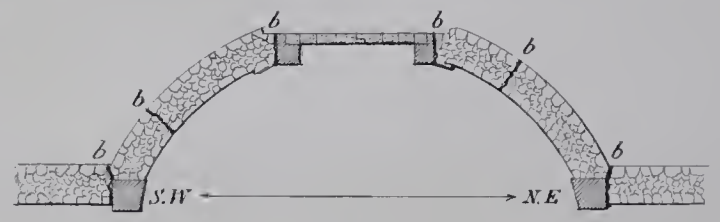


Fig. 8





ROAD

Fig12

30 N. of E. ——— 30 S of W.

Fig. 9

Fig. 15.

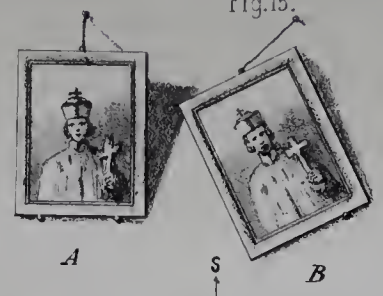


Fig. 14

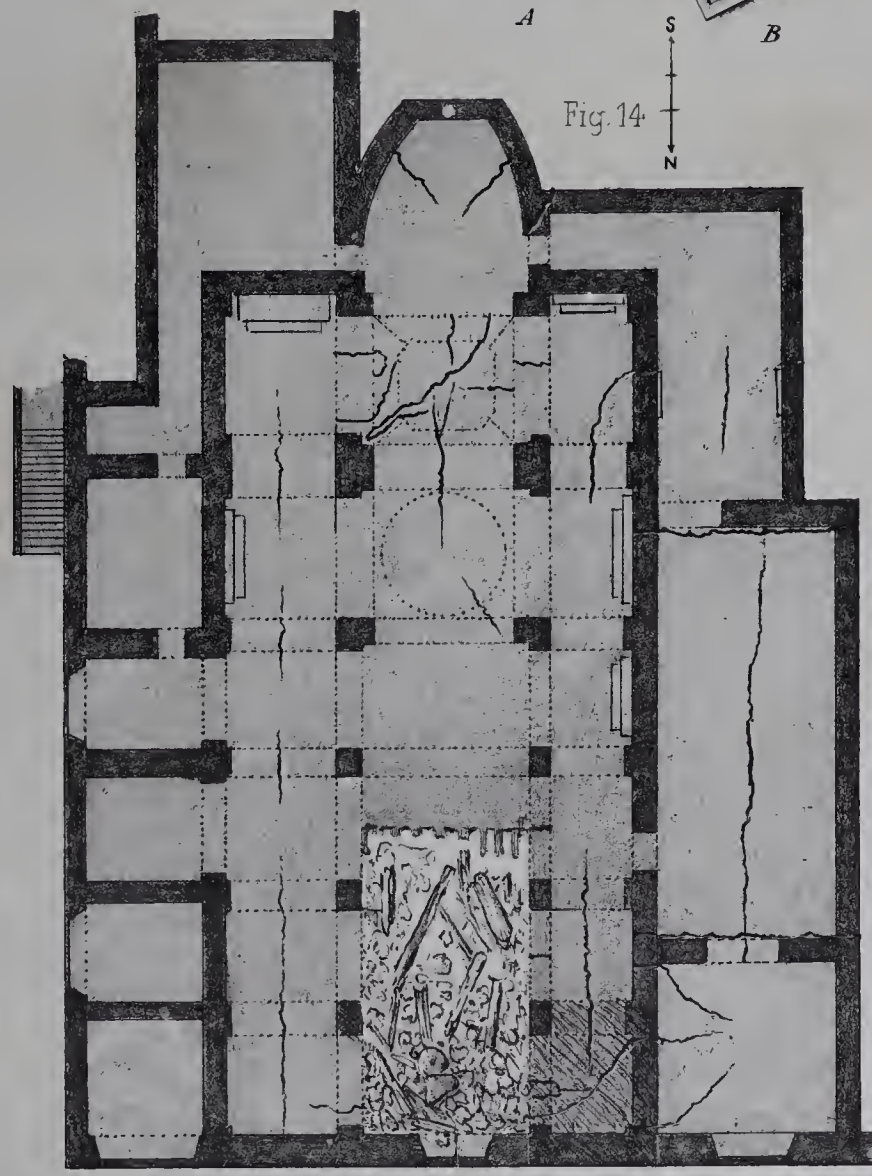


Fig. 13

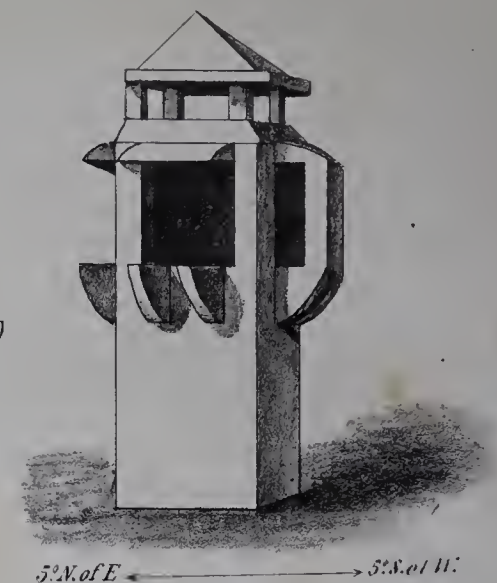


Fig 11

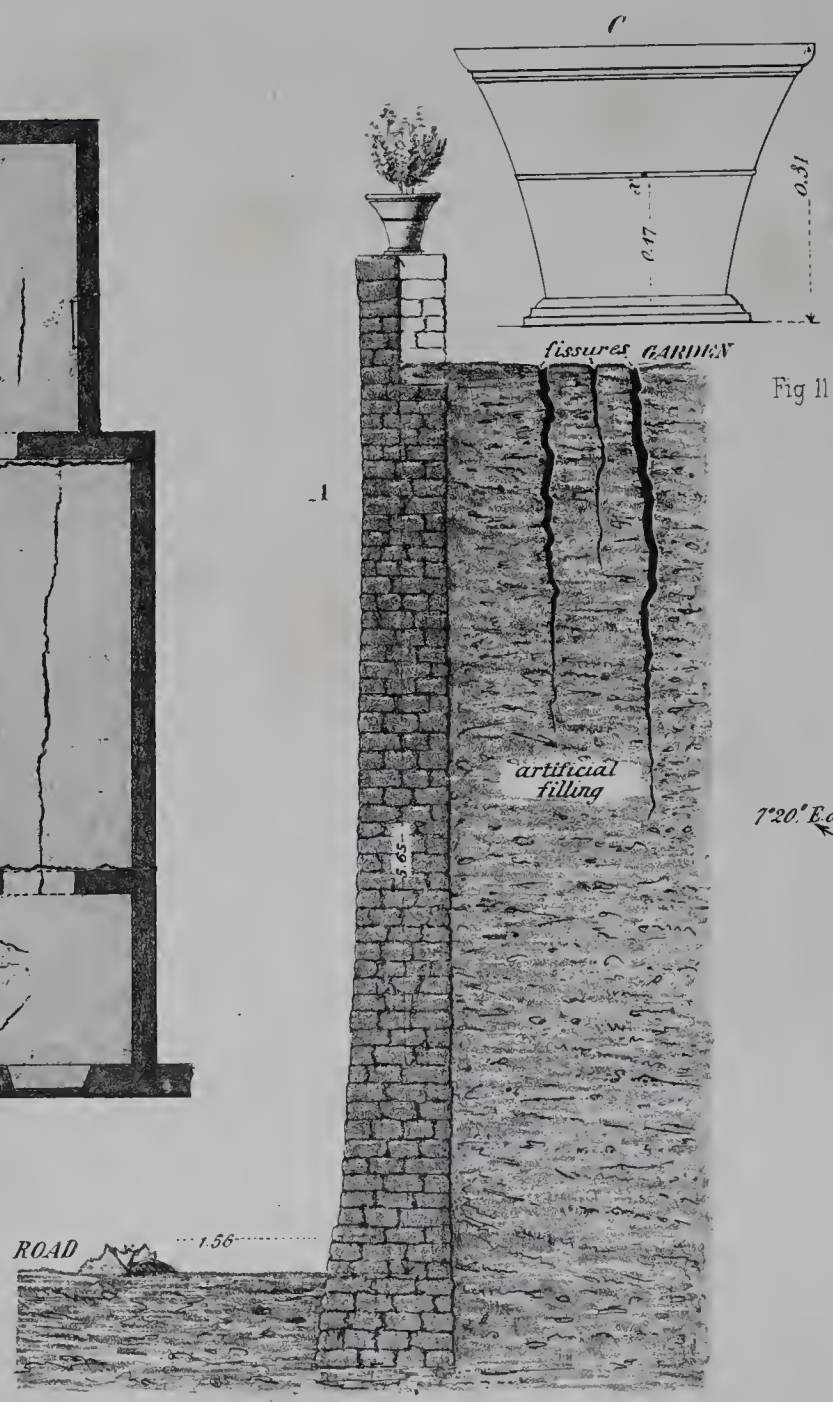
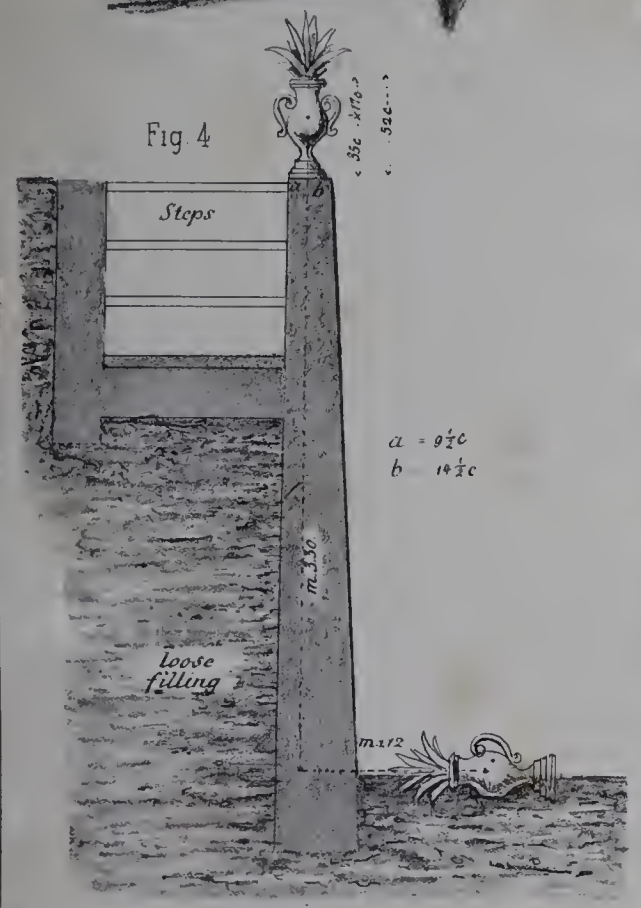
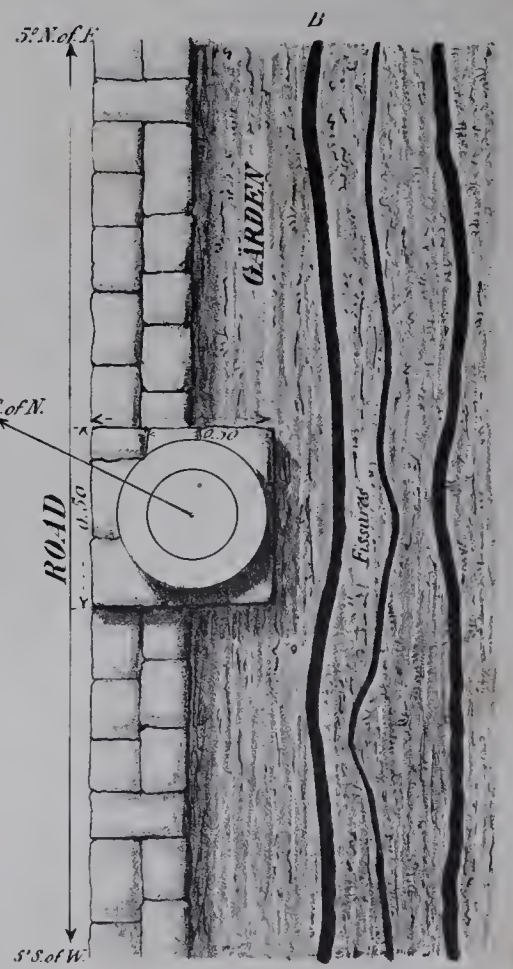


Fig 4





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Distance in miles of 60 to the degree from the perpendicular of the Royal Observatory of Naples

Distance in miles of 60 to the degree from the perpendicular of the Royal Observatory of Naples

Figure 2.

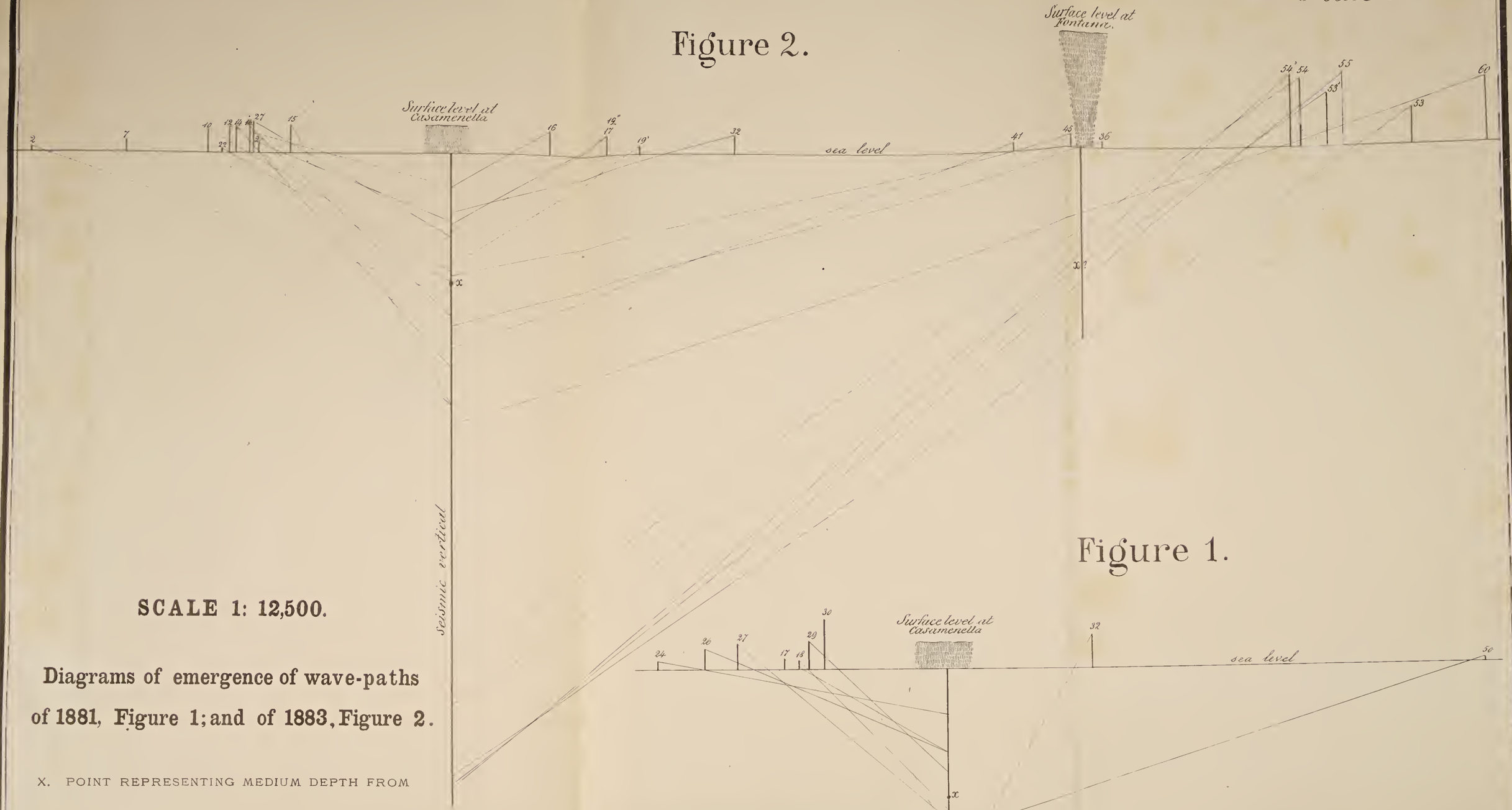

Figure 1.

SCALE 1: 12,500.

Diagrams of emergence of wave-paths of 1881, Figure 1; and of 1883, Figure 2.

X. POINT REPRESENTING MEDIUM DEPTH FROM THE SURFACE OF THE JUNCTION OF WAVE-PATHS WITH THE SEISMIC VERTICAL.

DOUBTFUL OBSERVATIONS ARE INDICATED BY DOTTED LINES.

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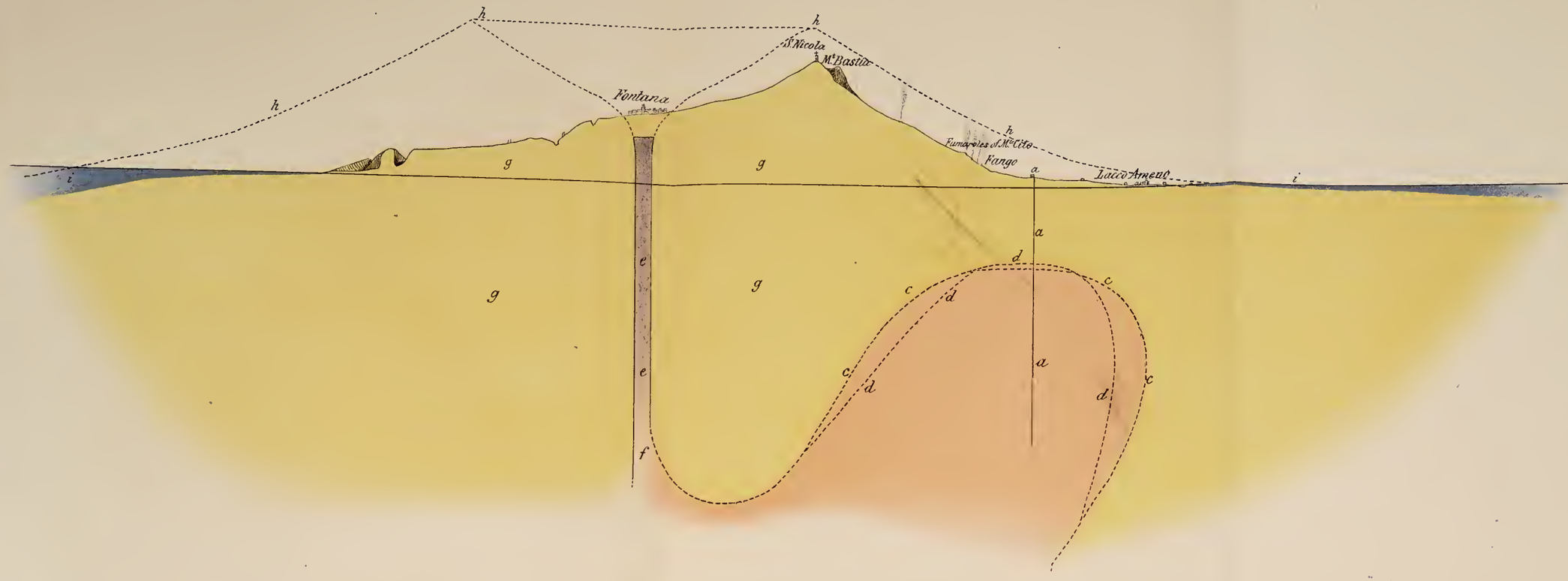
Plate 6.



DIAGRAMATIC SECTION of the ISLAND of ISCHIA through the plane of fracture. TRUE SCALE of 1 in 25,000, vert.l and horiz.l

Sea

Tufas and other rocks forming the mass of the island

Old chimney of Epomeo, plugged by cooled and compact Trachyte

Molten lava filling the focal fissure

a. *Epicentre and seismic vertical.* c: *Mean limits of the focal cavity of* 1883. d. *Same of* 1881. e. *Plugged main vent of the volcano.*

f. *Portion of magma still fluid.* g. *Compact and loose tufas of Epomeo, possibly older volcanic products and sedimentary rocks.*

h. *Probable primitive form of the volcano before denudation commenced.*

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